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Midshipman W. S. Mitchell
U. S. Naval Academy
June 9th 1886

TREATISE

ON

MARINE AND NAVAL ARCHITECTURE,

OR

THEORY AND PRACTICE

BLENDED IN

SHIP BUILDING.

BY

JOHN W. GRIFFITHS,

MARINE AND NAVAL ARCHITECT.

ILLUSTRATED WITH MORE THAN FIFTY ENGRAVINGS.

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EXPLANATION OF CHARACTERS;

ALSO, DECIMAL AND FRACTIONAL PARTS OF A FOOT, USED IN THE WORK

= Equal to, as 144 square inches = 1 square foot.

+ Plus, or more, signifies addition, as $3+3+6+9=21$.

— Minus, or less, signifies subtraction, as $10-5=5$.

× Multiplication, or multiplied by, or into, as $7 \times 9=63$.

÷ Signifies division, as $63 \div 9=7$.

: :: Signifies proportion that is, as $3 : 6 :: 18 : 36$.

. Decimal point signifies, when prefixed to a number, that the number has a unite for its denominator as .1 is $\frac{1}{10}$. 01 is $\frac{1}{100}$, or .792 $\frac{792}{1000}$.

The decimal parts of a foot are expressed in the table on the left; and the common fractional parts of the foot, as found on the 12 inch rule, will be found in the tables on the right: the latter is used in taking off tables from the model; the former is used in tables of displacements. The decimal and fractional parts will apply equally to all the inches of the foot, as well as the first.

$\frac{1}{16}$ of an inch,	0.01
$\frac{1}{8}$ " "	0.02
$\frac{3}{16}$ " "	0.03
$\frac{1}{4}$ " "	0.04
$\frac{5}{16}$ " "	0.05
$\frac{3}{8}$ " "	0.06
$\frac{7}{16}$ " "	0.07
1 inch	0.08
2 inches	0.17
3 " "	0.25
4 " "	0.33
5 " "	0.42
6 " "	0.5
7 " "	0.58
8 " "	0.66
9 " "	0.75
10 " "	0.83
11 " "	0.92
12 " "	1.

Ft. In. Eighths.			
0	0	1,	or $\frac{1}{8}$ of an inch.
0	0	2,	" $\frac{1}{4}$ " "
0	0	3,	" $\frac{3}{8}$ " "
0	0	4,	" $\frac{1}{2}$ " "
0	0	5,	" $\frac{5}{8}$ " "
0	0	6,	" $\frac{3}{4}$ " "
0	0	7,	" $\frac{7}{8}$ " "
0	1	0	1 inch.
0	2	0	"
0	3	0	"
0	4	0	"
0	5	0	"
0	6	0	"
0	7	0	"
0	8	0	"
0	9	0	"
0	10	0	"
0	11	0	"
1	0	0	"

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PREFACE.

In the dedication of this work to the Shipwrights of the United States, the Author has no apology to offer.

However much may have been published by Naval Architects in the old world, it is but too plain to the thinking mechanic that the science of Ship building is yet in its infancy.

The efforts of European authors to impart such information as shall meet the wants of operative mechanics, to qualify them for the responsibilities of builders, have thus far proved abortive both in the old and new world; the reasons are obvious.

The very limited amount of information their works contain upon the branches connected with the merchant service, in connexion with their complex character, and want of adaptation to the technical terms used in the United States, has proved, and must continue to prove, a barrier to their extensive circulation in this country.

Comparatively few American mechanics bury their talents within the walls of a navy or dock yard, consequently, works on Naval Architecture are of little service in the western world. The economy of our government exhibits the utility of a small, but efficient naval force, while maritime enterprise points to our merchant ships as the bulwark of her defence. To this enterprise we are indebted for the symmetry and efficiency accredited to American ships throughout the commercial world.

This work is designed to form the connecting link between science and practice, with a view to the elementary instruction of those who have not previously studied the principles of science in modelling and building ships.

But while it is designed as the novice's guide, it will be found to contain much information adapted to all branches of maritime enterprise; not

only the elementary principles, but all the departments of this science will be distinctly explained and illustrated by plates and diagrams. The subject of masting and sparring vessels, that has been considered beyond the grasp of scientific men, will be explained in its proper department.

Popularity has not been sought at the expense of science, nor brevity by the sacrifice of useful information and appropriate illustrations. The work contains not a few original improve-

ments, and it is confidently believed that it will not only be found to embody in all departments, the latest improvements, but to be in advance of the age, in this complicated art.

Finally, in submitting the work to the judgment of the mechanical and mercantile community, the author may, perhaps, be allowed to say, that he has left no means untried that appeared likely to ensure the accuracy and excellence of the work.

JOHN W. GRIFFITHS.

MARINE AND NAVAL ARCHITECTURE.

CHAPTER I.

Early History of Ship Building—The cause of its Decline—Its Revival during the Middle Ages—Reasons why so little is known of the Art from History—Equilibrium of Fluids—Laws of Buoyancy elucidated—The Importance of Stability, and the Laws that Govern it.

No leaf from the pages of antiquity can contribute so much towards endowing posterity with a correct knowledge of the race of man, as that which narrates the progress of Science and Art. As no descriptive exhibitions of the tree equals that of its fruit, so no expositions of the workings of mind so fully develop the capacities of the inner and the outer man, as the work of his hands. In scanning the musty folios of the past, it would seem that a second deluge had swept every page of the history of mechanical science from the face of the earth. Our reductive energies are shackled by historians, who have delighted to luxuriate on the rise, progress and ruin of their race, while the most prolific mines of Science and Art have been left unexplored; the most valuable discoveries to the commercial world have been consigned to the incendiary's torch, or doomed to the tomb of Capulets; the exuberance of language has been exhausted to laud the hero, and foster a spirit of military glory; the bloody riots of butchers of their race, and the desolating march of tyrants, have been narrated with redundant effusion. The irretrievable loss of information respecting the prominent mechanics of early ages, may be attributed to the unsophisticated dogmas of such men as Plato, who poured out ebullitions of wrath against his followers for debasing the excellence of geometry, by applying it to sensible things. Thus, the waves of oblivion cover the crumbling temple and its builder in the same solitary grave. The baleful shadows of the past become thick and impenetrable, like the midnight of Egypt; the fluctuating tide of time leaves only the mound between the furrows on its shores, to mark the spot where nations sleep. Alas! this unsparing scythe has swept over the glories of the past,

and thus we read the fate of the present. The lover of antiquarian knowledge strains his eager vision in poring over the musty pages of the past—he looks in vain to find anything calculated to make him wiser, surviving the wreck of time. The philosopher sighs and mourns over the desolation. The man of science weeps as he looks at the almost universal blank. The agriculturalist is palsied in amazement at the silence that everywhere reigns, on the subject of sustaining animal life. The mechanic is led to exclaim: If the past can furnish no wholesome admonitions for the future, let it perish from the recollection for ever; let the mantle of oblivious drapery cover its crumbling pyramids and solitary graves! It is nothing to know what our ancestors were, unless it be accompanied with the desire to emulate their virtues and avoid their errors. What, though the mildew of mythology cover the past; and like the simoon of the desert, commissioned to obliterate all impressions, and leave one wide-spreading waste! But our Creator has, in benevolence, as in wisdom, adapted our mental constitutions to our moral responsibilities, and permitted us to weave the rainbow of anticipation on the dark rolling clouds that overshadow the past. How willingly, when thus illumined, do we recur to periods of by-gone greatness,

and throw ourselves on the bosom of the tempestuous wave, feeling at ease amid boisterous commotion, as one relic leads to the remembrance of another. It is thus associations become, in our hand, a golden chain, the links of which lead us through the misty labyrinths of commingling thought, to the birth-place of their existence. Whenever we attempt to penetrate the veil of obscurity, that mantles from our view the work of ancient mechanics, we are led to regret that some one of their number did not, for the sake of posterity, undertake to give a graphic description of the state of mechanical science. Many learned men of old deemed it the part of wisdom to conceal in mysticism all discoveries in science. This custom was so prevalent at one time, that philosophers refused to leave anything in writing explaining their researches. How vast the change! The world, in modern times, would give more to witness the evolutions of the Athenian Ship-yard, than to witness the battles of all the marshalled armies of their race.

The light of science, mental, moral, and physical, have dispelled the gloom of barbarism, and given a powerful impetus to man's career, down to the latest future in the vista of time.—Alas, for the scruples of Plato and his coadjutors! However unwilling

some few shreds of ancient mechanism have found a conveyance to posterity, although mingled with the narration of political convulsions, and honored heroes all bathed in human gore! And though the relics of ancient mechanism crumble into dust with the weight of centuries—the hush of shipwreck and the briny deep, that great charnel-house which has swallowed up millions of our race, and mantled in oblivion every vestige of the art—no towering pyramids, or massive columns, point generations, yet unborn, to the skill of their ancestors; little remains above the wide-spread ocean to show what was the form of that engine of war, or the messenger of peace. The mythological story of the famous Argonautic expedition, by Janos and his companions, seems to represent the result of some bold commercial expedition after the golden fleece of Phyrxus, that far outstripped all the previous discoveries of its time, by which Greek maritime knowledge was extended to the farthest shores of the Euxine, and bears a strong resemblance to the golden expeditions of the present time. Little doubt exists of the Phœnicians having been the discoverers of the Art of Sailing; their skill in evading the vigilance of Nebuchadnezzar, at the siege of Tyre, which lasted thirteen years, escaping with the wealth of the city in

their vessels, when they could no longer defend it; and this, too, about five hundred and seventy years before the Christian era, shows that they possessed more than a superficial knowledge of commercial pursuits. The great naval victory obtained by the Greeks over Xerxes, (520 years B. C.,) would lead us to conclude that the art of constructing vessels was known and practised to a considerable extent, more particularly when we remember that Xerxes had a fleet of twelve hundred and seven vessels, each capable of carrying two hundred and thirty men, engaged in the combat. The very fact of the Grecian mariners making use of the screw-pump, introduced by Achimedes, to discharge water from their vessels' holds, would lead us to conclude that their vessels were not mere shallops, as those of Europe in more modern times. Early records which are, doubtless, worthy of credit, state, that when the Chaldeans, under Nebuchadnezzar, conquered Egypt, they struck terror into the hearts of the Egyptians, at the sight of their vessels; this was five hundred and seventy-two years before the Christian era; the Egyptians themselves never navigated the ocean, being prejudiced against the sea, because it swallowed up the river which they worshipped. Hence, the reason why they never attempted to construct vessels of

any considerable size. They first traversed the river Nile upon rafts, then in the canoe, these were succeeded by the boat built with joist, fastened together with wooden pins, and rendered watertight by interposing the leaves of the papyrus; to this boat was, at length, added a mast of Acanthus, and sail of papyrus. The Phœnecians were a nation nearly as ancient as the Egyptians; situated directly on the sea, without the advantages of a noble river, they were compelled to provide means for sailing on a wider expanse of water. It is said, however, that they first traversed the Mediterranean, and even visited distant islands, with no better means of conveyance than a raft of timber. This is rendered more probable from the fact, that the Peruvians, even in modern times, ventured on the Pacific Ocean on their balza, a raft made of a spongy tree of that name. The vessels first constructed by the Phœnecians were used for commercial purposes: they were flat-bottomed, broad, and of a small draught of water; and those of the Carthagenians and Greeks were similar in shape. By successive improvements the ships of antiquity were at length brought to combine good proportions and considerable beauty. We learn from Athenius, that Archimedes, that illustrious philosopher, who lived 250 years B. C., exhibited a skill in the art of building ships, that, in some respects, is scarcely surpassed at the present day. A ship requiring three hundred men one year to build, could, by no means, have been considered an insignificant affair, more particularly when we are told that she had three decks, and as many masts; having also an engine for assaulting purposes, capable of throwing stones of three hundred pounds weight a distance of two hundred and twenty yards; possessing, also, engines for grappling with the enemy, and guards of iron to prevent them from boarding; the stanchions which supported the upper deck represented statues of Atlas, nine feet long; she was fastened throughout with copper bolts, none weighing less than ten pounds each; on the middle deck were thirty rooms, in each of which were four beds, all the inventions of Archimedes himself. In addition to the force required to operate her engines of death, twelve hundred young men formed her complement for operations. The wonders of this ponderous fabric were not alone exhibited in her size and powerful armament,—her baths, gardens, conservatory for fish, library, room for Venus, the Goddess of Beauty and Love; in addition to the various embellishments and contrivances for all the services of life, her ceilings represented the spangled heavens; she

had a single screw pump, by the use of which one man could pump out all the water that leaked into her; she was also supplied with machines, similar to our forcing pumps, for raising water. She was supplied with twenty ranges of oars, and twelve anchors, eight of which were of iron. She was named the Syracusan, and sent as a present to the king of Egypt, laden with corn, and subsequently named the Alexandria.

The bows of vessels, in the earlier ages, were denominated the *prout*, and ornamented with eyes, as those of the Chinese at the present time; and in many cases decorated with sculptured figures of heathen deities, and otherwise adorned with paint and gilding, while the sterns, which were usually in the form of shields, were elaborately wrought in carved work, (a practice adhered to at the present time.)

The vessels first used for war-like purposes were mere row-boats, although termed ships-of-war. They were much smaller than merchant craft, and rendered so for convenience in working them, in which the combatants rushed upon each other, and decided the combat by valor and physical strength. As they increased in size they became more formidable, and were armed with an iron beak, with which the contending parties often

stove in the sides of each other's vessels.

After the Phœnicians discovered the art of sailing, all their vessels were provided with a single mast that could be elevated or taken down at pleasure; they were also provided with oars, and thus propelled when occasion required. While in this stage of advancement, they were stranded at the termination of every voyage, and were thus drawn upon the shore for several centuries, with but few exceptions, in which they were too large. The addition of a keel, and the increase in size, soon made it impracticable. At this time sheet-lead sheathing came into use; the anchor and cable came in for their share of the laurels (about the same time) with which to decorate the brow of the inventor. The first anchor was nothing more than a large stone; afterwards wood, and finally iron, was the sole material. Improving in size, as in other qualities, they became about as large as what was subsequently termed galleys, with one, two, and three banks of oars.—When in battle the combatants contended above, being in part defended from the missiles of opposing foes by towers and screens placed on deck, and by shields carried on the arm. The approved length of a merchant ship was four times its breadth, while those

for war purposes were from six to eight times their breadth. From these proportions arose the distinction of long ships and round ships, or, as we would transpose the term, to sharp ships and full ships: thus we discover, that the ancients, more than two thousand years ago, knew what many of our commercial men have yet to learn. The general size of merchant ships in the best days of antiquity, was not greater than that of our sloops and schooners; but there are instances on record which prove that they occasionally equalled in capacity those of modern times. The destruction of commerce, caused by the general desolations of the northern barbarians, and the ruthless incursions of those heathen conquerors, diverted the channels of commerce from their legitimate field of operation, and caused all the intercourse, as well as the expedition of a warlike character, to be conducted on land. The invasion of the Roman empire had much to do with causing a retrogression. In some parts of Europe it almost extinguished the art of building vessels: and it soon dwindled into insignificance, and thus remained until the middle ages, when the active trade which arose in the Mediterranean, and the naval enterprises connected with the Crusades, occasioned a revival of the art. Yet it did not advance beyond

the condition in which the Carthaginians left it, until the middle of the fourteenth century. Alas, for the commercial world! that the transcendent art should lie amid the smouldering ruins of obscurity; should be mantled with the drapery of blood, for nearly fifteen hundred years! At this era the inconsiderable galleys of former times began to be superseded by larger vessels, in which, however, oars were not entirely dispensed with. The great change in the general construction of vessels arose from the discovery of the polarity of the magnet, and the application of astronomy to nautical pursuits; for by the aid of these means the mariner was released from his dependence on the sight of land in guiding his vessel on its course.

To the Italians, Catalans, and Portuguese, was ship building mostly indebted in the early ages of its revival. The Spaniards followed up their discovery of the new world with rapid improvements in both the form and size of their ships, some of which have been rated at two thousand tons burthen. In more modern times the French, in connexion with the Spaniards, are entitled to the credit of nearly all the improvements which have been made in the theory of the art. Although those made by the English have been of some importance,

yet they have been, and are, to the present day, behind the age in many important matters pertaining to the art, their contributions never having been commensurate with the advantages they possessed for advancement, although the greatest naval power of this or any other time. Her narrow-minded policy in this branch of commercial enterprise, causing her to rear restrictive barriers against foreigners, has proved fatal to her commercial interests. This fatality will, doubtless, be more plainly seen, now that the bulwarks restricting her intercourse in navigation, between mother and daughter, have been broken down. Its effects are but too manifest, not only in her works on ship building, but in her dock-yards its blighting influence is seen and felt, like mildew in every department of hereditary knowledge,—this great enemy of improvement.

Foreign, and particularly English authors, have frankly admitted, that there are abstruse questions connected with the art of building merchant ships upon the principles of science, that does not exist in the construction of vessels of war; and with every facility afforded them in Europe, they almost universally announce the art of building ships to be one of analogies and comparisons. Not an author has dared to do more than reite-

rate the hoary traditions of their ancestors. The commercial world has had abundant proof, that theory without practical knowledge is like a steam-boat without an engine, a steam boiler without fuel, or an axe in the hands of the man who has not learned its use. It is not the author's province to induct American mechanics into the glories of commerce, the great engine by which the blessings of civilization have been diffused throughout the world; or to linger around the smouldering portals of antiquated cities, to show what have been the advantages of commerce to our ancestors. But we may go back a distance in the vista of time, only commensurate with the history of this Republic, and view the commercial condition of Europe and America. Look at England, whose national policy has been strictly commercial; with unbounded resources for improvements, the canvas of whose ships whitened every sea,—whose power and influence was felt in every clime! what has she not done to maintain her supremacy? She abandoned her tonnage laws, and adopted another code, calculated to give an impetus to her own commerce, and at the same time to fetter American genius. Failing to accomplish her designs, she sought other fields of operations, in the construction of Ocean Steamers: learned, in

1838, that which Americans had learned more than twenty years previous; and, but for the timely assistance of the British government, the enterprise would have been relinquished.

Contrast the ebullitions of the English press at the successful termination of their first voyage made by steam across the Atlantic, with the history of steam navigation in the western world, and the contemplative mind will be constrained to regard the Anglo-Saxon as a working rather than a boasting race. Scarcely ten years had elapsed after Fulton had made his first passage to Albany, by the aid of steam, when Americans were ploughing the trackless deep by the same agency. The ocean steamship Savannah, as she approached Cape Clear, was reported in Liverpool, by telegraph, to be a ship on fire; and His Majesty's cutter was sent to her relief. Their chagrin and amazement may be imagined at the discovery, that with all sail set, in a fast sailing vessel, they could not overhaul this thing of life under bare poles. The prosecution of the voyage from Liverpool to Copenhagen, Stockholm, St. Petersburg, Arendal in Norway, and her safe return to the United States, at once solved the problem of the feasibility of navigating the ocean by steam, and at the same time exhibits the fecundity of American

genius. But her owners had learned something more than the mere fact, that it was possible: they had learned, that steam power for long voyages was unprofitable, unless endowed with certain privileges that sailing vessels did not possess. Hence the reason of its abandonment, until our government should find it necessary to foster the enterprise. The silent footfall of time obliterated from the public mind the sensation produced by this achievement, without bombastic eruptions.

The fact is too palpably plain to be for a moment questioned, that Americans have much more to gain by ocean steam navigation than other nations. Hence the reason why all Europe manifested so much surprise at the torpidity of Americans in embarking into this great commercial scheme. The American character seems to be but partially known abroad. It is only necessary for him to receive an affirmative answer to the question, *will it pay?* when he gathers up his scattered thoughts, and concentrates them into a single idea, or into the compass of a telegraphic despatch; and then, as on wings of lightning, he is ready to circumnavigate the globe, or to embark in any enterprise within the grasp of thought, or the conception of the human mind.

What, may we not inquire, is the

standard value of American ships abroad? Is it not universally admitted, that Americans surpass all other nations on the globe in the superiority of their vessels for commercial purposes?

Let us now turn our eyes homeward and see what can be done. There are few of our prominent ship-builders in the United States, who, (under a judicious code of tonnage laws,) do not see in the future greater improvements than the world has yet witnessed. We pause to inquire, from whence have they obtained this perspective glance, the outline of such stupendous improvements? The casual observer may have supposed, from works on naval architecture; but let one of their number speak for himself, and before introducing him, let me add, that no man upon earth enjoys a better reputation as a practical builder. In a conversation upon this subject with David Brown, he said, "it has always appeared to me that naval architects have done all they could to mystify the theory of ship-building; subjects that are plain have been rendered intricate, and costly works have been abandoned on this account." Let the reader decide, whether science without practice, or theory and practice combined, are most likely to accomplish the work of revolutionizing the commercial world. The genius of American institutions

has imparted an indomitable energy of Herculean power to her favored sons, that surmounts every obstacle, and knows no barrier. The boundless fields open on every side, marking no distinctive lines of birth or wealth; but affording genius of *every* grade an opportunity for development, and its consequent reward. On the other hand, it must not be supposed that energy alone is a universal Alcahest.

The prejudices interwoven with the present mode of modelling ships, cling to the builder like the poisonous ivy to the monarch of the wood, binding his thinking powers with fetters, which, if not rent asunder, will cause him, like the oak, to perish in their palsyng embrace. The streams of knowledge, connected with the art of building ships upon the principles of philosophy, have been poisoned at the fountain. Rustic and philosopher, sage, sire, and school-boy, all have drunk at the muddy pool. The hoary head of prejudice, mantled with a guise of experience, dams up the streams of knowledge, and hurls defiance at the man who dares to assert that the fields of science are open alike to all. The man who builds one hundred ships by the same model, contracted or expanded, has had no more real experience than the man who has built but one. It is impossible to model vessels by the eye, having

no reference to known laws that govern the elements. They are designed to navigate without becoming familiarized with a certain shape that pleases us, and from which we cannot depart, that every ship-builder is fettered with a shape peculiar to his notion; and the ship is as indelibly stamped with lineal genealogy, as hereditary lineaments are visible in the human face.

It is not my purpose to tax the reader's forbearance with a detailed history of the discrepancies of the present, or to draw an analysis of the principles that has governed the progress of the art, as recorded on the historic page. Were we thus disposed, we should find ourselves encompassed by the trammelling influence of prejudice, which has not been confined to the old world, but has been transmitted to the shores of this Republic, and has already spread over a surface as wide as the commercial interests of our country.

Science, in its most comprehensive sense, may be classed under two heads: a knowledge of reasons, and their conclusions, constitute abstract; that of causes and their effects, and of the laws of nature, natural science. Marine architecture, or the art of building ships upon scientific principles, may be regarded as the legitimate offspring of natural science. Hence the necessity

of a knowledge of the laws governing non-elastic fluids, and of solid bodies floating on fluids. The state of fluidity may be defined as that property in bodies which tends to form drops: and this property does not exist in but one of the three states in which matter exists, namely, the solid, the fluid, and the gaseous. The solid may be reduced to powder, and is found to possess no fluidity. Some writers make a distinction between fluid and liquid, confining the latter term to those substances whose particles adhere to other bodies plunged into them. Thus, mercury and air are fluids, but not liquids; they leave no moisture on other bodies immersed in them; while water and alcohol are both fluid and liquid. It may be remarked here, that the terms elastic and non-elastic are used in a relative sense, and not in an absolute; for water, and probably all other fluids of the same class, are, to a certain extent, compressible and elastic, though they resist compression with a very great force. Writers have attempted to give mechanical ideas of a fluid body, but the impossibility of giving any kind of mechanical comminution, must appear obvious, if we but consider the circumstances necessary to constitute a fluid body. First, that the parts, notwithstanding any compression, may be moved in relation to each other, with

the smallest conceivable force, the particles or molecules, (for such is the distinctive and appropriate term, when applied to the very minute parts of a fluid,) yield to any force, however small; and by so yielding are easily moved among themselves, and give no sensible resistance to motion within the mass, in any direction. Second, That the parts shall gravitate to each other, whereby they have a constant tendency to arrange themselves around a common centre, and assume a spherical form, which is easily executed in small bodies, inasmuch as the parts do not resist motion: hence the appearance of drops always takes place when a fluid is in proper condition. The dew-drop stands out in drastic contrast with solid bodies, similarly circumstanced. Being a liquid, it must of necessity gravitate towards the centre; hence the reason of its globular form, and the facility with which the particles may be moved towards each other. It will be perceived, that were it possessed of the inherent properties of matter in a solid state, it could not be raised above the surface of a vessel, or heaped up in a spherical form, as the reader may have often witnessed. Solid bodies can by no means conform to these conditions; they gravitate downwards, or toward the centre of the earth, while a fluid body may be divided

and subdivided into the smallest conceivable molecules, and each particle will adjust itself around a common centre. This independent action of fluid bodies, denominated equilibrium, is a property which has perplexed not only the mass of mankind, but learned men in every age.

From what has been shown, it follows, that the essential difference between fluids and solids, consists in the equilibrated gravity of the former, or their equal pressure in all directions—upwards, downwards, obliquely or laterally. The whole doctrine of the equilibrium of fluids is deduced from this fundamental law.

Whence, if any particle sustained a greater pressure in one direction than another, it would, necessarily, by reason of the absolute facility of motion, and the extreme lubricity with which it is endowed, give way and move towards that part where the resistance is least, and, consequently, there would be no equilibrium. One of the obvious consequences of this property is, that its surface, when at rest in an open vessel, and acted upon by no other force than attraction, is horizontal or perpendicular to the direction of gravity; if the gravitating forces are parallel, the surface, as a consequence, will be a plane, free from inequalities. If they tend to one point from different

places, or all converge to the same point, the surface of the liquid will be a sphere. Such is the ocean, bending away from a perfectly straight line, eight inches in every mile; but by reason of the magnitude of the sphere, the curvature of any small portion is imperceptible, and may be regarded as a plane. The pressure of a fluid on all and every particle of the vessel containing it, or any other surface in contact with it, is equal at the same altitude. From this proposition it obviously follows, that the pressure on the bottom of the vessel depends entirely on the area of the bottom and the depth of the liquid, and is entirely independent of the force of the sides, and of the quantity of liquid in the vessel. This proposition gives rise to such results as, at first view, appear most absurd; and, as a consequence, has been termed the *hydrostatic paradox*, which may be defined on a larger scale, sufficiently comprehensible to an ordinary mind. A column of water of half an inch, or even less in thickness, will as effectually float the largest ship, as the whole ocean; and abundant proof of this is afforded at every wharf or pier at which vessels are moored. Vessels are there seen preserving an equilibrium, with a small column of water on one side, and the river's whole breadth on the other.

The appended diagram will doubtless make this law of equilibrated gravity in fluids so plain, that further expositions will be unnecessary. (See Fig. 1.) It is the altitude that determines the pressure, and not the bulk. It will be observed that the diagram represents the water at the same height on both sides of the ship. Without this equilibrium the ocean would be of no service to man; vessels might be built, but they never could be sent to sea, the preponderating power of the ocean (being the largest bulk) pressing upon every coast, and upon every river and outlet, would for ever lock every vessel to its native shore. Upon this principle a few ounces of water may be made to support any weight, however great. Many striking phenomena of the material world are deduced from this principle. A pipe having an internal surface of 1 foot, or an interior circumference of 1 foot, or 4 inches diameter, the area of such pipe would be 1 foot, which multiplied by 1 foot, or 12 inches of length, equals 144 square inches. If such pipe were extended 140 feet perpendicular, the lower section, already described, would sustain a bursting pressure of 8640 pounds, which is about equal to that produced on many high pressure steam boilers. A column of water, the area of whose section is one square inch, and of which the height is 27.727, or







nearly 28 inches, weighs 1 pound, and 28 inches are contained 60 times in 140 feet. Hence the lower end of the pipe, 1 foot from the base, must sustain this enormous pressure, because 144 inches, the contents of the foot of pipe, multiplied by 60, gives 8,640; and this pressure would remain unchanged, however much the pipe might be altered at the top, while its perpendicular height remained; because, while the altitude remained the same, the weight of a column of water of 140 feet in length, 1 foot area, is pressing upon the base, and being a frictionless body, must press with the same weight, even though the upper 139 feet of the pipe be but 1 inch in diameter. If a farther illustration were necessary, it might be obtained in witnessing the result of boring a hole in the bottom of a ship when afloat,—we at once see the fluid ascending with a pressure proportionate to the area of the hole. If the fluid did not exert a pressure upward as well as downward, it would be a difficult matter to account, upon philosophical principles, for this freak of nature. It will readily be perceived that the atmospheric pressure which universally covers matter, whether solid or fluid, has not been removed from the ship's hold, and, as a consequence, the same amount of pressure is operating upon the area of the aperture that is exerted at the

surface of the fluid. It would, doubtless, be considered superfluous to pursue these illustrations farther, as it is believed the subject has been made sufficiently clear to an ordinary mind. Although water is a body, and a non-elastic fluid, yet it may readily be decomposed, and reduced to a gaseous state. It is a curious fact, that notwithstanding its qualities to quench fire, its component parts (without chemical combination) constitute the most combustible and explosive compound known; and at the freezing point, contains 140 degrees of latent or secret heat. It is a good conductor of sound, and is entirely free from frictional properties, inasmuch as the commingling influence of a small quantity of the fluid poured into the ocean, affects all the water therein contained, and sets in motion *every* particle of its enormous bulk.

Although water is a frictionless body, and at all times maintains an equilibrated surface, and cannot be lashed into commotion by itself, yet we see it sometimes threatening to rend into fragments the boasted representative of man's ingenuity and power. It is the friction caused by the action of the wind upon the surface of the fluid that causes such wondrous results. The casual observer would be led to conclude, that the equilibrium of fluids

exists only in the brain of the adherents to this dogma; the progression of the wave would appear to annihilate every vestige of such theory. But upon a more minute examination we find that the wave has not a progressive motion; when the fluid is set in motion by agitation, the mass is not transferred, as will appear manifest upon observing any light body upon the surface. The appearance of progression is but a deception of the eye, caused by the form of the wave, and the mode of its oscillations. By close attention it will be seen that the fore part is always in the act of rising, and the hinder part in the act of falling; and thus the whole mass appears to roll onward, while each particle of water merely oscillates successively, with a vertical ascent and descent. The cause of this reciprocating motion may be thus defined;—when the surface of the water is unequally pressed by the wind, the columns sustaining the greatest pressure sink below the original level; this pressure being communicated to the adjacent columns, causes them to rise above the level, and this lengthened column having no hydraulic pressure or balancing power to sustain it, again falls, and in its descent acquires a velocity proportionate to its height, descending below the level, and in its turn communicates a pressure to the contiguous columns. Thus, by the particles to which the original impulse was given, being alternately higher and lower, a series of waves are formed, consequent upon the force and unequal pressure of the wind. But if this free oscillation be prevented by shallow water or rocks, so that the columns in deep water are not balanced by those in the shallow, they in consequence acquire a progressive motion towards the shallower water or rocks, and form breakers: hence the reason why waves always break against the shore, it matters not what is the direction of the wind. It has been often asked why so much damage is done at sea, if the waves have not a progressive motion? This is partly owing to the strength of the wind, and partly to the influence of the passing or approaching vessel—the side of the wave presented to the wind acquires a gentle slope, while the opposite or lee side is perpendicular when at its summit, and its own weight added to the power of the wind, while the balancing column is cut off by the proximity of the vessel, causing it to strike with destructive force. The progressive wave sent forward by a vessel in motion (or generated in any other manner) differs entirely, not only in its character, but in its phenomena, from the oscillatory waves of the ocean, or such as ripple the surface of a lake, or are caused by

the sudden elevation or depression of a small portion of the fluid. It does not, necessarily, arbitrarily demand a depression or elevation, but is a single elevation of a well defined form, and transferred with uniform velocity to the contiguous mass. This wave is, by Mr. Russell, said to be analogous to the tide wave, which travels at the rate of 1,000 miles per hour, and would circumnavigate the globe in a lunar day. The limits of this work prohibits more than a cursory glance at this interesting subject. The reader is referred to the reports of the British Association of 1838, for details. The author does not feel free to occupy a space commensurate with the importance of investigating subjects that do not immediately pertain to the subject before him; although the cause, formation, size, and comparative strength of the ocean wave is a subject well worthy the attention of every builder, in endeavoring to approximate the resistance to be overcome, and the power he possesses of subduing it.

The laws of equilibrated gravity in fluids having been established, the buoyant property of the fluid will be next considered. A body floating in a fluid is pressed upward by a force equal to the weight of the fluid it displaces or sets aside, and the weight of the entire body is exactly equal to the displaced

bulk, regardless of its size or shape. If the specific gravity of the fluid be greater, the body will displace less, because a smaller bulk is equivalent to the weight of the body; for example, a ship will not sink as deep if the water be salt, as though it were fresh; nor would it be immersed as deep at sea as in a fresh water river, notwithstanding the weight of the ship might be precisely the same in both cases. If the density of the fluid be less the body will sink deeper, because a greater bulk of the fluid is required to compensate the loss of weight in an equal bulk; therefore, in all cases the water displaced by a floating body will be equal in weight to that body. But as described in a former hypothesis, on the constituent properties of the fluid, it does not follow that a smaller bulk of fluid would not float a ship; but it does follow, that however small the column of water may be, the altitude must remain the same, as illustrated by the diagram of the ship at the pier preserving her equilibrium, or balanced by the small column between herself and the pier, so that there must be a line of immersion, or a line of flotation, equivalent to the weight of every floating body; but the external fulcrum, or line of flotation, remains unaltered only under the following circumstances, viz.: while the weight of the ship remains the same,

and the fluid remains undisturbed, for water is found to be less buoyant when in commotion than when at rest. Hence the reason why steam-boats careen to the disturbed side when one water-wheel is suddenly revolved. It will appear obvious, that when the fluid beneath or around a vessel is disturbed, from whatever cause, in the same ratio the necessary support is drawn from the vessel, and as a consequence, she must yield to the side thus disturbed. This is apparent from two causes: first, the pressure on the undisturbed side is the greatest, and consequently the preponderating power must be felt; while, by disturbing the fluid we take away a portion of the support required to sustain the weight, and the vessel careens until she finds an equivalent line of flotation. It is from this fundamental law that the weight of all floating bodies may be determined: the weight which a body has when wholly immersed in a fluid, is equal to the weight of an equal bulk of the fluid. We do not mean by this, as in the case of the body partly submerged, that the immersed portion, and the bulk of displaced fluid are equal in weight. In the case of immersion it matters not whether it weighs more or less than the fluid, whether it be cork or lead. In the case of lead, it, of course, would sink, but would weigh as much less in the water than in air, as the bulk of water it displaced: whereas the cork would require a pressure downward to submerge it, equal to the difference of its own weight in air and a bulk of water of equal magnitude. If this weight were applied to the cork it would be exactly equipoised, without the application of force. When it is stated that a body loses part of its weight in a fluid, it must not be supposed that its absolute weight is less than it was before, but that it is partly supported by the reaction of the fluid under it, or the upward pressure, so that it requires less power to sustain or balance it. This proposition, which is capable of strict demonstration, may be also illustrated as follows: Suppose any interior portion of a liquid to become solid, it would evidently remain in the same state of indifference or equilibrium as before. It must, therefore, be borne up by the vertical pressure of the fluid, with a force just equal to its weight, or which is the same, to the weight of the fluid, whose place it occupies; and if we conceive this congealed mass to have its weight increased or diminished, it will be pulled downwards or upwards by the difference between its new weight and the weight of an equal bulk of the fluid. It is the same if we substitute any solid body instead of this block of ice. The equilibrium of solid bodies

floating on fluids, is an important part of hydrostatics, in consequence of its relation to the proper construction of ships. The laws of gravitation teach us that all solid bodies gravitate toward the surface of the earth, and at the same time have a central point within themselves, which is so situated that a line or plane passing through the body, and cutting at the same time the centre of gravity, whether equally or unequally dividing them, will render their weight equal. Hence it follows, that if the centre of gravity be sustained, the whole body will remain at rest, whether supported from beneath, or sustained from above, for the weights on both sides of this vertical plane, or perpendicular line, passing through the line of support or centre of gravity, being equal, the body can have no tendency to angular motion. But we must distinguish between the effects of gravity and that of weight; gravity has no dependence upon the mass, while weight depends entirely upon it. For example, in a vacuum, or a reservoir from which air has been extracted, a feather will obey the laws of gravity as easily as a lump of lead; and having been started from the top at the same time, would also reach the bottom at the same time. But when exposed to the atmosphere we find that by reason of the density of the lead, or the bulk of matter it contains, or its excess of weight, that it falls much faster than the feather. The centre of gravity is an imaginary point or axis; every body has a centre of gravity, and so has every system of bodies. It is not always within the body itself; the centre of gravity of a ring is not in the ring; neither is the centre of gravity of a ship in the materials of which she is built; it forms no part of the structure itself, and yet there can be no structure without its having this central point. Thus it will be perceived that the centre of gravity is an imaginary axis, around which solid bodies will oscillate when circumscribed by but a single fluid, or wholly immersed in air, water or any other fluid; varying the position of the body will not cause a change in the centre of gravity, since any such change will be nothing more than changing the direction of the forces, without their ceasing to be parallel; and if the forces do not remain the same—are increased or diminished as the body approaches or recedes from the point of attraction; still the forces upon all the particles of which the body is composed, vary proportionally, and their centres remain unchanged. If, when a body stands upon a plane, a vertical or perpendicular line passing through the centre of gravity, falls within the base on

which the body stands, it will not fall over; but if the vertical line falls without the base, the body will fall, unless it be prevented by external support. When the vertical line falls upon the extreme edge of the base, the body may stand, but its equilibrium, or its stability is so small that it may be disturbed by a very trifling force, while the nearer the vertical line falls to the centre of the base, the more firmly will the body stand. To find the centre of gravity mechanically, it is only necessary to dispose the body successively in two positions of equilibrium. This may be exemplified by particularizing a few methods. Suppose the body to be the model of a ship made for the purposes of calculations, without screws or dowels, as in all cases twin models should be made, where accuracy is required. Insert a tack in the surface of the plane representing the middle line near the extreme point of intersection of rail, with knight-head, from which suspend the model by a line, hang a plummet from the same point of suspension, and when at rest mark the intersection of the line with the plane or straight surface of the model; the model may now be suspended by the other extremity, representing the intersection of the rail with the stern; when suspended from this point, a plummet may be hung from the point

of suspension, as before, and its intersection with the surface of the middle line, and where the line crosses the former plumb-line of suspension, or the point of intersection, is the centre of gravity, as in fig. 2.; or the model may be suspended by two lines from the same point, but attached to different parts of the model, or the same points designated in the first example. A plummet suspended from the same point will fall on the centre of gravity. In this example, if the lines are of equal length, the centre of gravity will be determined longitudinally only; but having ascertained its longitudinal location, one of the lines may be lengthened, and the operation again performed, when the plummet's intersection with the former mark will determine its altitude: see fig. 2.

The same process may be resorted to in determining the centre of buoyancy, by separating the model at the load, or any line of flotation, below which the centre of displacement is required, as in fig. 3. It is, doubtless, perfectly clear to the thinking man, that if we obtain the location of this point, longitudinally and vertically, that we have it transversely, inasmuch as the plane surface representing the centre of the vessel transversely, must of necessity confine its transverse location to that plane, as the exact location of the centre of displacement is a vastly im-





portant consideration in determining the ratio of stability the vessel may possess, and is the only index for the proper location of the engines of steamers. It is necessary that some pains should be taken in determining this point. Its location may be found on the model, without knowing the actual amount of the displacement, or the aggregate bulk of water displaced. This, however, may also be determined by the model; but when the draft of the ship is the field of operations, the amount of displacement must be known, to locate its centre, and this can only be known by calculating the area of every parallel section, (to the line of flotation,) or base line, according as the sheer-plan may be disposed, or the difference in draught of water be determined upon, whether parallel draught, or most at the stern. When the buoyancy is so arranged that the vessel will draw the greatest draught aft, the difference is in spacing the first line above the base; and, as a consequence, the remaining ordinates or parallel lines should be equidistant from each other. Some builders determine the longitudinal centre of displacement, by separating the model, and applying the edge of a knife or any appropriate instrument, for this purpose, to the square edge of the section, with its surfaces or planes in a vertical position, the edge of the knife being the fulcrum, either the section or fulcrum may be shifted until it is balanced, when its equilibrating point is noted or marked on the middle line or square edge of the section. This method is adopted with each section, below the greatest immersed line of flotation, when the mean of the whole is determined, according to the ratio of the bulk of each section. But this method is objectionable. Building models, or models made for building purposes, are usually screwed together, without reference in the distribution of the screws to any mechanical method of equilibrating; and mechanics, in common with the rest of mankind, are easily led to believe what they wish to be true. Hence they avoid the necessity of making a model *fac-simile* of the first, for the purposes of calculations, or twin models, as they are sometimes called. The variation in consequence of the holes for the screws, being very nearly equally distributed, is so small, that it will furnish the required points with sufficient accuracy for all practical purposes. It is important that another model should be made, to which the thickness of the plank should be added; it may be glued together as high as the load-line of flotation, at which line it should be left free for separation; the top-side, or the section above the line of immersion,

may also have the thickness of the plank added, and its several sections or shear pieces glued together. When the several methods, already described, for obtaining the centre of gravity and centre of displacement, or the centre of gravity of the displacement, are conducted with care, the location determined is sufficiently reliable for any and every practical purpose. There are several methods of obtaining the displacement, or the actual bulk of water displaced by a vessel, two of which only are necessary. The first is, with the aid of the model, in which case a box made of some material that will not absorb the water; the box should be made by such dimension as will ensure the immersion of the model. At one end, near the top, (which should be open) a facit may be inserted, and at the bottom, on the inside of the box, a small pulley may be fastened, through which a horse-hair, or some very fine line may lead to the top, sufficiently long to fasten one end to the model, while the other end, leading through the pulley, will come above the top of the box. A nice pair of balances should now be prefixed, having a concave scale at one or both ends of the beam, sufficiently large to contain a bulk of water equal to the bulk of the model, and adjusted with one scale immediately under the facit and having the appro-

priate weights at hand; the box may now be filled with pure rain or distilled water, as high as the facit will allow without leakage; the model should be suspended by the line, and carefully lowered into the box until it finds its balance in its buoyant properties, when the end of the line leading through the pulley may be slowly taken in, until the model is immersed, as in Fig. 4, when it will be found that a bulk of water, exactly equal to the model which represents half of the immersed portion of the vessel, is deposited in the scale under the facit. The water may now be weighed, and the displacement readily computed in the following manner: For the sake of convenience we have assumed the model to have been made upon a scale of 38.4 of a foot, or when the foot is divided into inches, eighths and sixteenths, it would be recognized as being $\frac{3}{8}$, or one quarter and one sixteenth. The reason for adopting this scale for the elucidation of this subject, is simply because it divides the cubic foot into 64,000 cubes, or cubic feet, represented in the model, each of which equals in bulk 7.5, or $7\frac{1}{2}$ grains of distilled water. By this hypothesis we have but to know or assume the weight of the bulk of water forced out of the box, and the tonnage is at hand; assuming the bulk to be 160 ounces, we have this formula.

MARINE AND NAVAL ARCHITECTURE.

Oz.	Grains.	Grains. Cubic per fl. feet.	Pounds per fl. feet.	Pounds	Pounds per ton.	Tons.	Pds.	Tons.	Pds.
160	=76,800	÷7.5=10,240	×62.5=640,000	÷2,240=285	+1,600	×2=571	+960		

Thus it is plain, that the displacement of one half of the vessel equals 285 tons, 1,600 pounds, while the entire displacement of both sides equals 571 tons and 960 pounds; it must be remembered that this is the weight of the vessel and cargo, when loaded to the greatest immersed line of flotation, and not the weight of the vessel alone, if it were built of such material, that its specific gravity and that of the model were alike, or the same, then the weight of the vessel could be determined by allowing the model to float in the box, with the top side annexed, and the bulk of water forced into the scale would denote the weight of the vessel by the same formula as has already been described. The laws of displacement are plain and easily understood. Every vessel displaces an amount of water, the bulk of which is of sufficient weight to compensate, or to equilibrate the weight of the vessel, and the difference between the lines of flotation that compensates the weight of the vessel, (sometimes called the launching line of flotation) and the greatest line of immersion is the displacement or bulk of water set aside by the cargo and stores, or whatever is put on board the vessel after the launching line is taken. It

will be found that there is a discrepancy in the calculation, if the cargo is weighed and compared with the displacement noted down at the several lines of flotation. This arises from the difference in the specific gravity of the water used in the hydrostatic balance, and that in which the vessel floats. Distilled or pure rain-water has been regarded as an invariable standard when under the same weight of air; hence the reason for selecting it. But the water in our rivers is variable in its weight, or its specific gravity. It is well-known that although water is a non-elastic fluid, (speaking in general terms) yet it is capable of containing accessions from the mineral kingdom, without increasing its bulk, although its specific gravity is augmented in proportion to the density and quantity of such increase. As has been already stated, the fluid being composed of infinitely small particles, of spherical or globular form; it is thus cavities are formed. A glass may be filled with water until it will contain no more, yet it will be found sufficiently capacious to contain sugar, alum, and salt. Hence it is clear that water may differ in its specific gravity, and that the less pure the more dense or greater its weight. And that it weighs less in a

state of purity than in any other state. In the exposition of the method of obtaining displacement by the aid of the hydrostatic balance, we have set down its specific gravity, when in a state of purity, at 1,000 ounces, while the mean specific gravity of sea-water, according to the experiments of the late Dr. Marcet, was found to equal 1.02777, near the equator. We are also informed that there is no notable difference between sea-water, under different meridians. Perhaps a homely illustration of some every-day occurrence may serve a better purpose than any other that I might be able to adduce. We

may have often seen a full measure of apples, and although no more could be pressed into the measure, yet it would contain various kinds of grain; and when thus doubly filled with apples and grain, it would hold water in addition to what it already contained: so with the fluid itself. The vessel will be found to draw less water at sea than the balance indicated; hence the necessity of an addition to the weight of the fluid, which is found to equal about 3 per cent., or one-thirtieth of its weight in solid matter, the bulk of which is chiefly salt. Thus, in the formula, instead of

$$\begin{array}{ccccccc} \text{Pounds.} & & & \text{Pda. per} & & & \\ & & & \text{Ton.} & \text{Tons.} & \text{Pda.} & \text{Tons.} & \text{Pda.} \\ 640,000 \div 2,240, \text{ we have, } & 640,000 + 19,200 = 659,200 \div 2,240 = 294 + 6402 = 588 + 1280 \end{array}$$

Or, the formula may be thus:

$$\begin{array}{ccccccc} \text{Pounds.} & & & \text{Tons.} & \text{Pda.} & & \text{Tons.} & \text{Pda.} \\ 640,000 + \frac{640,000 \times 3}{100} = 659,200 \div 2,240 = 294 + 640 \times 2 = 588 + 1280 \end{array}$$

This additional weight will not be necessary for the navigation of our lakes, although the use of the hydrostatic balance is one of the most efficient and reliable modes of determining the amount of displacement from the model, unless by actual computation, which exacts a tax of time which few builders are willing to submit. There are other modes of facilitating the work that are, perhaps, worthy of our attention; a box may be made, as in the former case, without reference to its contents,

of a material that will not absorb the fluid, with a facet in its end, and a pulley arranged, as in the former case. Another box should also be prepared, of the same material, the internal contents of which may be known, as follows: A box in the form of a cube of 1.05 inches, will contain 64 cubic feet, or 2.5 will contain 512 cubic feet, or a cube of 5 inches, will contain 4.096 feet, we have assumed the scale to remain unchanged, as in the first example of the hydrostatic balance. The

box itself in which the model is immersed may be thus apportioned on its sides, by marking the scale of contents in the ratio, as given, and the displacement may be determined, without farther trouble, by the computation of cubic feet into tons, as per example, assuming the box to have an area of 5×1 (feet,) then we have this formula, 5 feet of length = 50 feet per scale, 1 foot of breadth = 10 feet per scale: thus, $50 \times 10 = 500$. Then we have, for every $\frac{5}{16}$ of height in the box, 500 cubic feet. There are two other methods of determining the amount of displacement, one by comparative bulk, the other by comparative weight. Assuming the model to be made of materials, the specific gravity of which is known, a block of the same material, and of the same specific gravity, in the form of a cube of 5 inches, which, by the last example, contains 4,096 cubic feet; and assuming the specific gravity to be equal to that of distilled water, both that of the model and block we have the following: If 4 pounds = the weight of the block containing 4,096 cubic feet, what will be the contents of the model, assuming the model to weigh 16 pounds. Thus we have the same results as before: 4 pounds weight of block contain 4,096 cubic feet, what are the contents of 10 pounds, the weight of the model?

Block	Weight of model.	Contents in feet of block.	Pds.	Cubic ft.	Pds. per foot.	Pounds.	Ton.	Tons.	Pds.	Tons.	Pds.
4,096	$\times 10$	$= 40,960$	$\div 4$	$= 10,240$	$\times 62.5$	$= 640,000$	$\div 2,240$	$= 285$	$+ 1,600$	$\times 2$	$= 571 + 960$

To this add the difference between distilled and salt water, 19,200 pounds, and we have,

$$640,000 + 19,200 = 659,200 \div 2,240 = 294 + 640 \times 2 = 588 + 1280$$

Thus we have the same results as before. There is another method that is sometimes adopted; but as it is liable to variations, and subjects the practitioner to error, unless the most rigid scrutiny is observed throughout the operation; and even under this test, I should only deem it safe where an approximation was all that I required. The mode alluded to has a similarity to the second example of the hydrostatic balance, with this exception, the medium is sand instead of water. Having prepared the two boxes, as in the case alluded to, we shall require a bulk of sand sufficient to fill the box, free from moats and every other impurity. It should be also perfectly dry, and the entire cubical contents of the box known. After which it may be filled,

with great care, through a sieve would be the preferable mode, as sand is to some extent like grain, and will settle in a smaller compass readily; the box being filled, the surplus above the edges may be carefully stricken off with the straight-edge or ruler. The surplus should now be removed, and a large cloth spread to receive the sand from the box, which being empty, is ready for that part of the model below the load-line, or line of immersion. If the model cannot be separated without injury, the surface representing the middle line may be placed against the side of the box, the load-line at the same time cutting the edge of the box. Thus having the immersed portion in the box, and emerged part out, when this method is taken, the box may be made of wood, and the sides and edges must be perfectly straight. The model having been adjusted in the box, the sand may now be put in, as before. Particular care should be taken that the methods of filling the box should be alike in both cases,—being filled to the edge, and stricken off by the edge on the box, and load-line on the model. The surplus, or that portion of sand the box will not contain, may now be measured by the small box prepared for the purpose; as in the second example of the hydrostatic balance. Assuming the model made for those several modes, to be made by the same scale, $\frac{5}{16}$ of an inch, a box of five inches square will contain 4,096 cubic feet; while on an inch scale, or $\frac{1}{16}$ of the foot, the box will contain but 125 cubic feet. Thus the importance will be readily discovered, of continuing to adopt the scale with which we begin our computation. Some may have supposed that the scale upon which a model is made should be without any fractional parts. And, as a necessary consequence, it may be more readily understood. But I have never been able to discover such advantage. Whenever calculations are to be made, it is certainly much more convenient to deal in round numbers; and to do this we may divide the foot into tenths; the scale assumed is a small fraction more than the $\frac{1}{40}$ of a foot: and to divide the foot into 40 equal parts, would be the correct mode of proceeding, as it will be discovered that were a sufficient number of $\frac{5}{16}$ added together, we would not find the scale to be the exact ratio, as 40 times $\frac{5}{16}$ would make $12\frac{1}{2}$ inches; but having adopted this scale as approximating the nearest to the scale in general use; and at the same time a very near approximation to the truth, it was deemed prudent to adopt the course as better calculated to illustrate the leading principles, than another scale that could not be found marked on the rule in general





use. It may be well to remark further, that in making models to build, or to make calculations from, it is always best to make a scale on a slip of paper, and if the practitioner is not sufficiently skilled in the use of the drawing-pen, he would realize the time well spent in learning its use. When we have lost the scale by which a model is made, the model is of no use unless the scale is known. Thus we have the key, and no man can, without much difficulty, make use of the model or drawing, without this key. It will be readily discovered, that if the scale is altered after the model is made, that it disproportion the vessel; and that by departing from the dimensions we lose the shape. For example, if the scale be increased from $\frac{5}{16}$ to $\frac{6}{16}$, or $\frac{3}{8}$, (the scale in general use) we diminish the size of the vessel. But this is not all; we alter the principal dimensions, and thus, by increasing the scale, we diminish the size of the vessel; and, by diminishing the scale, while the model remains the same size, we increase the size of the vessel. A vessel 100 feet long, 25 feet wide, and $12\frac{1}{2}$ feet deep, by the scale we have assumed in our foregoing examples, $\frac{5}{16}$, would measure, by an increase of the scale to $\frac{6}{16}$, or $\frac{3}{8}$, 83 feet 4 inches long, 20 feet 8 inches wide, and 10 feet 4 inches deep, while, by reducing the scale to $\frac{1}{16}$, or $\frac{1}{4}$ of an inch, we have the

vessel increased to 125 feet long, 31 feet wide, and $15\frac{1}{2}$ feet deep. Thus, it will be readily discovered, that the scale is to the model, what the key is to the lock; and if we adopt another scale we alter the model or shape of the vessel. It does not, however, follow that a scale cannot be made to answer the purposes of expanding and contracting models or draughts, and yet retain the shape and proportionate dimensions. This can be accomplished, and will be fully explained in its proper place.

There is yet another mode of determining the displacement, by the use of the model separated at the line of immersion. And if this mode be deemed preferable, reference should be had to it when the model is made, which should be glued together. In the selection of materials for the model, enough should be reserved out of the middle of the board to make a water-line section, as shown in the appended diagram, Fig. 5. It will be observed, that although this mode of operation is denominated *comparative weight*, yet it depends materially upon the specific gravity of the material. Hence the necessity of selecting all the pieces of which the block is composed, from the middle of the same board of which the ends are taken for the model, the top end of the board forming one length of

water-line, and the butt-end another, the middle being the block, would be the mean density of the board. It will also be observed by the diagram, that the pieces are equal in thickness, and precisely the same as those of the model. And this being the case, it is only necessary to determine how many cubic feet is equal to the required displacement, (remembering that the number of water-line pieces and the depth of the block compare exactly with the depth of the model.) Having thus ascertained the number of feet required to equal half the displacement, or half the model, it remains to reduce the block to its equivalent size. In the example given in the diagram, the depth of the model is twelve feet, as is also the block. Thus we discover that the half model contains 849 tons 1,920 pounds; or the block equals a bulk of water which would weigh that amount; and, as the model is of equal weight, contains the same amount of tons. As we have thus given all the available modes of determining the displacement from the model, we shall next investigate the manner of accomplishing the same from the draught. Few vessels are built in the United States from the draught; and, as a consequence, ship-wrights in general are unacquainted with its advantages in obtaining the ratio of stability, expansion,

&c. Hence one of the reasons why the draught is repudiated by the casual observer. In calculating the amount of displacement, or the number of cubic feet of water displaced below a given line of immersion, we assume that the draught is divided into longitudinal sections, parallel to the line of immersion, usually called water lines. To determine the amount of displacement is to compute the area of each of those planes or water-lines from the half-breadth plan, (which shows the shape of the vessel longitudinally,) and the cubical contents of the spaces between those lines. In Europe, the line of flotation, or the inscribed line at the surface of the water, is called the first water-line, or load-line, and as they descend the numbers increase. In the United States the lowest water-line is denominated the first, and the numbers increase as we ascend. The greatest immersed line of flotation is universally called the load-line; and the usual mode of calculation commences with the load-line, which is divided into equal spaces, by lines running at right angles with the middle line in the half-breadth plan. Those lines represent frames, and are numbered in the after-body, (or from the largest frame toward the stern,) and lettered in the fore-body, (or from the largest frame toward the bow,)

commencing at the extreme breadth or greatest transverse section. In thus dividing the ship longitudinally into sections, it is in all cases proper to place this frame, representing the greatest breadth, and having the greatest area, in such place that it may prove to be what it represents. It is usually denominated *dead flat*, from its having less rise on the floor than the rest of the frames in the ship. It is usually marked ⊗. The location of this frame should be known before the shape of the half-breadth plan is determined. It will be seen, that to make the spaces equal between the frames, the division or setting off must proceed from ⊗ frame in each body; and that if the frames are to be $2\frac{1}{2}$ feet apart, every fourth frame will be 10 feet apart. It will be only necessary for our present purpose to consider the fourth frames, until we approach the extremities, when we may include every second frame, and at the extremes, sometimes, every frame. See the Displacement Tables of Plate 2.

The stability of vessels is an important branch of hydrostatics, and is among the first considerations that should engage the attention of the builder. There are two kinds of stability, natural and artificial, speaking in general terms.

It has been already shown, that the

bulk of water displaced by the vessel must have a central point or axis upon which it would equilibrate if congealed. And this has been denominated the centre of displacement, or the centre of gravity of displacement. It does not, however, follow as a consequence, that this point is to be found only in the centre of the cavity, either longitudinally or vertically; but if the two sides of the vessel are alike, it will always be found in the centre, transversely, when the vessel is upright. Neither does it follow, that this assumed axis is immovable, or always in the same place; but whenever the vessel is careened, or drawn aside from an upright position, or a change takes place in the shape of the line of flotation, the centre of gravity of displacement changes its location, unless the body is homogeneous, or of such shape as to create no change in the form of the cavity. In such case, if the body is of equal density the centre of gravity becomes the axis. A second axiom may be deduced from this law of equilibrated gravity in bulks, in the seeming paradox, that the centre of gravity is not the centre of motion. In all bodies floating on fluids, and only partially immersed, the line or point of support has a separate and distinct location, unless as before stated. The body is homogeneous in shape, and of equal density; in such

case it has no stability. It will appear quite manifest, upon a moment's reflection, apart from the conclusions drawn from mathematical investigation, that a body having its centre of gravity depressed below its vertical centre, and suspended by a point above the vertical centre, such body would be subject to less oscillatory motion, than if suspended at the centre of gravity. Hence it follows, that to depress the centre of gravity, and elevate the point of support, is to increase the stability of a body thus suspended. It is a conceded point, a truth with which all are familiar, that all bodies are supported by the centre of gravity; and that it requires a force more than equal to the weight of the entire bulk, to lift that body when applied to this centre; and that the body thus suspended has no stability, but revolves around this centre. Not so, however, with a body, or vessel, floating on a fluid and sustaining the pressure of two elements—the centre of gravity loses its influence as a point of support, because the fluid beneath is non-elastic, and of greater density than the fluid above. Thus it is plain, that the forces of the fluid upward must exceed the forces of the fluid downward, or there is no stability. The effort of the water's power to sustain a vessel in an upright position, passes through the centre of cavity, or

gravity of displacement, and the direction of its effort is perpendicular to the surface of the fluid. Therefore, if a vessel is at rest, and in smooth water, her centre of gravity is in the mean direction of the effort of the water which supports her. When a vessel is inclined, or heels, she should have a tendency in herself, without ballast, to regain her upright position: that is to say, her centre of gravity ought to be so sustained, that the effort of the vessel's weight should concur with the effort of the water to right her. This concurrence of efforts is what may be properly termed stability, and its proportions may be measured; and as the inches upon a rule show the proportions of a foot, so the altitude of the point I shall denominate the centre of effort, may be measured, and the amount of stability determined. It should be remembered, that the centre of effort is that point in the vertical section of the vessel's length, at the middle line, under which the centre of gravity of the vessel ought always to be, in order to prevent the vessel from falling on her beam ends, or turning bottom up.

The measure of stability, or centre of effort, is also a moveable point, and changes its position at every change in the line of flotation, the stability of the vessel being determined by the altitude of the centre of effort, or its distance

from the centre of gravity, which remains unaltered while the vessel's weight is the same, and is homogeneous. It will be necessary, in order that the reader may be made familiar with the locality of those moveable points, to make a proper distinction between the two centres of gravity; that of the entire vessel we shall denominate the centre of absolute gravity, while the centre of gravity of displacement we may know as the centre of cavity, or under its former appellation. It will be perceived, that as the vessel is immersed by the reception of cargo to a more elevated line of flotation, the centre of the absolute gravity descends, not because the body is heavier, but because it is not homogeneous, or because the lower part of the vessel is heavier than the topsides by the additional weight of cargo, the centre of cavity has taken a higher position consequent upon the increased displacement, and as every addition to the displacement must take place at the surface of the fluid and increase the altitude of the line of flotation, so the results of such increase will be seen in the increased altitude of the centre of this displaced bulk of fluid or the centre of cavity. The centre of effort may be thus defined: It is the centre of direction of all the forces that support the vessel; this leads us to a point,

the consideration of which we will defer to a subsequent chapter. The equilibrium of fluids should teach us this truth, that the pressure of the fluid, or the direction of the resistance, is at right angles with the surface of the body, or the exterior surface of the cavity made by the vessel; hence, it follows, that to find the centre of effort of a floating body, is to find the centre of that force enabling a ship to preserve an equilibrium perpendicular to the surface of the fluid by which she is sustained. This point is always found to be in the centre of cavity when the vessel is in an upright position, and it is equally apparent, that when a vessel is at rest in smooth water, the centre of gravity is in the mean direction of the effort of the fluid that sustains her. In other words, the centre of effort is the centre of the foreign power that deprives the centre of gravity of much of its influence in floating bodies. It will be readily seen, that, were lines drawn at right angles from every part of the exterior surface of the vessel inward, to the longitudinal and vertical plane extending through the vessel, or the line known as the middle line, those lines running from the section near the keel, would point higher than those coming from the bilge, and those coming from the bilge would extend higher than others

near the surface. Thus, the sum total of the effort of all those lines of direction, either adjacent to the keel and pointing upwards, or those from the bilge and pointing diagonally, or those near the surface and pointing horizontally, the sum total of those efforts is the point I have denominated the centre of effort. Hence, it follows, that the altitude of the centre of effort upon which so much depends, is consequent upon the dimensions more than artificial means, and as we increase the breadth of vessels, we elevate it; so, in the same ratio we depress it when we diminish the breadth or increase the depth. A case in point may serve as an exposition to illustrate the principles upon which the stability of all vessels depend, perhaps better than any the author may be able to adduce.—Assuming, that a ship built for commercial purposes is found to possess a precarious amount of stability, and as a consequence, must carry ballast in her hold to create an artificial stability and secure an upright position; we will now determine the location of the centre of the absolute gravity, the centre of cavity, and the centre of effort; the two latter, in this instance, will remain stationary, while the centre of absolute gravity will be the moveable point, when a change in the location of the ballast takes place. Having the precise location of all the moveable centres, we will now proceed cautiously to remove the ballast on deck. We shall perceive that the stability of the vessel diminishes very fast, and before the ballast is half removed from the hold, it will be necessary to use precautionary measures to maintain an upright position, or the position the vessel maintained when we commenced. Under such circumstances, is it not plain that the centre of cavity has remained in the same place? The vessel displaces no more water than before, the ship and ballast weigh the same, whether it is all in the hold, or part in the hold and part on deck; and as it is the centre of the bulk of water, and the bulk is the same, so in like manner the centre must be at the same point. It is equally as palpable that the centre of effort has remained in the same place, as that point is delegated to represent all the forces of the lines of direction of the immersed part of the hull; and if the immersed surface remains unchanged, both in form and bulk, the nature and extent of that delegation are the same. We will now inquire into the nature and extent of the change that has produced such wondrous results. We have already discovered that the centre of gravity is an immoveable point, while the weight of the body remains

unchanged, and is homogenous; but, although the ship and ballast weigh precisely the same, whether in the hold or on deck, yet the body or the ship, in this instance, is not homogeneous; when the ballast was in the hold, the bottom was the most dense; and now, as consequent upon the change, the topsides are more, and the bottom is less dense; hence the reason of the instability when the ballast is removed, the centre of gravity has changed its position, its altitude has been increased. This leads us to another proposition: neither the centre of effort, the centre of cavity, or the centre of gravity is the oscillating point or the fulcrum upon which this stupendous fabric moves. When the centre of gravity is located below the surface of the fluid, the oscillating point is found at the surface; but when the centre of gravity is at the same, or a greater altitude, itself becomes the oscillating point, as all bodies above the surface of the water oscillate upon that point. The several centres may be represented by the ordinary store-keepers' scale-beam; upon the nail or point of suspension depends the weight of the scales, weights, and articles weighed; this point is at a greater altitude than the fulcrum upon which the beam oscillates, while the scales, in their distended capacity, are found still lower. So with those points of measurement of stability; the centre of effort to which is delegated the power of contending with a combination of forces emanating from two elements, is the highest power; the fulcrum, or the oscillating point, or centre of motion, is located at the surface, as the fulcrum is at the surface of the beam, while the centre of cavity and the centre of gravity take their places, like the scales at less elevated positions. From what has been shown, this truth is deducible, that by increasing the breadth of a vessel, we increase the stability, and elevate the centre of effort, or increase the distance between the centre of effort and the centre of absolute gravity. But, another fact worthy of our consideration claims our attention. Every vessel has a natural position, or a position peculiar to the shape of the vessel when launched. For example, if the greatest transverse section is forward of the longitudinal centre, and the usual proportional expansion of the lines forward, and contraction aft, take place in the formation of the vessel, it causes her to set by the stern; this is a fact with which all are familiar, but it must not be supposed that the launching line of flotation is the natural line of immersion. In order to obtain this, the model should be separated at the line of flotation, at which the na-

tural position is required. Another illustration may serve better: A log of timber is said to be propelled with a given speed with less force the butt end foremost than the small end; the reason of this is, that nearly all of the resistance to be overcome, is found at the ends, the pressure of the water being at right angles with the bottom and sides of the log; in connection with the fact, that the log draws the most water at the butt, which materially diminishes the friction when the log is in motion; whereas, if the small end were foremost, the friction would be augmented by this right-angled pressure. Philosophers have, by this oversight, done the science of ship-building no material service. Builders have been led to suppose that a full bow, and a thin after end, with large buttocks to keep the vessel from going down aft altogether, was the proper shape. I shall endeavour to show, in the proper department of this work, that this error has proved fatal to the commercial world. In civil architecture, an extravagance or a blunder, may be an eye-sore to men of taste, and render the projector of the design ridiculous; but in marine and naval architecture, it too often proves fatal to human life.

We may be able to give another exposition of the laws of stability, by a

practical illustration from a pine log. It is well known, that a log straight and squared both ways to an equal size, whose specific gravity does not exceed three-quarters of the specific gravity of water, will not float with either of its planes parallel to the surface of the water; assuming that its specific gravity is exactly three-quarters that of the water in which it floats, with which, under some circumstances, yellow pine is found to comply with the already expressed terms of proportion. From what has been shown, a bulk of water, three-quarters of the entire bulk of the log, will weigh as much as the entire log; hence, it follows, that only three-quarters of the log will be immersed, or that a line of flotation, three-quarters of the distance up from the base on the two perpendicular planes or sides, would satisfy the demands of weight. The log is supposed to be homogeneous, hence, the centre of the absolute gravity is found in the centre of the log longitudinally, and the centre of motion is at the surface, the centre of effort is found to be at the centre of gravity; hence, it is plain there is no stability while the log remains with one of its planes parallel to the surface of the water, and will not rest until it assumes a position that will separate the centre of effort from the centre of the

absolute gravity at the farthest possible distance ; and if this separation cannot be made, the log will have no stability in any position ; hence, the reason why a log, as described, will assume a position, in which two of its corners form a vertical line, and the other two being at right angles with the first, will, as a consequence, be parallel to the surface. Thus it will be seen at once, that the right-angled pressure from the exterior surface inward, is of a more elevated character, and raises the centre of effort above the centre of absolute gravity, in the same ratio that the proportion of breadth is increased over the draft of water. Assuming the log to have been 12 inches square, the draft of water was 9 inches, while the breadth was 12 ; but when the log was canted, the breadth was 17 inches, while the draft of water was but 11. In the former case, the centre of cavity was one inch and a half below the centre of absolute gravity, while in the latter it was but one inch ; thus it is plain that the stability of the log did not depend upon the depressed location of the centre of cavity ; had this been the case, the stability would have been greatest when the surface of the log was parallel to the horizon, as it was then at the lowest possible point. Is it not plain that the direction of the exterior pressure is upward from the lower edge to

the extreme corners ? Hence it follows, that the centre of effort has taken a more elevated position, and as in this position the centre of effort has its highest possible location, so also the log, in this position, has its greatest stability. From this simple illustration, we may deduce this truth, that vessels having no more breadth than depth, have no stability ; a fact too well demonstrated by vessels that have been built in the Eastern states. The principal dimensions of vessels have much to do with their performances beyond their stability ; a small addition to the topsides, in a manner that does not affect their depth at the usual measuring point, may not only greatly diminish their stability, but affect and counteract the very object for which such addition was made. The ship-owner does not seem to realize, that for the additional 50 tons of weight he has added to the weight of the ship, in what is usually termed top-hamper, or in houses, poop-deck, high bulwarks, &c., that he is compelled to carry 100 tons of ballast more than without it ; thus, one hundred and fifty tons of displacement are lost, or worse than lost, being actually an injury to the performing qualities of the ship. The notion of having a large topside on a small bottom, is without a basis in the principles of sound philosophy in ship-

building, its deleterious effects will be shown in connection with the baneful effects of the tonnage laws as a first cause of disproportions. It should be remembered, that about one-third of the length of most vessels has no stability, and as a consequence, the counteracting leverage must be supported by the bulkier parts of the vessel; hence, it follows, that to increase the length, (while at the same time we possess a due proportion of breadth,) is to increase the stability of a vessel—another demonstrable truth in relation to the stability of vessels. It is well known that ships have been built with their greatest transverse section so formed, that its extreme breadth was depressed below the launching line of flotation, while the depth was increased beyond what it would have been in an ordinary formed vessel, under the false notion, that if the breadth were depressed, the vessel would be rendered more stable than otherwise. This, to some extent, is true; while the vessel is without cargo, she covers a larger surface than she would otherwise, and as a consequence, the centre of effort is higher, and the centre of the absolute gravity lower, by such a distribution of breadth, and such vessels are often found to maintain an upright position without ballast, with their spars and rigging adjusted; but

let such ship receive her cargo, and perform her intended voyage, and the story is soon told. She is found to be one of the most uneasy vessels that navigate the ocean. The reason will appear obvious to the thinking man, that it is because there is an undue proportion of buoyancy near the base, and an insufficiency at the load-line of flotation; the consequences are plain to be seen: this expanded buoyancy near the base receives nearly all the upward pressure, and, consequently, has a tendency to trip the vessel, while at the surface there is an insufficiency of buoyancy to counteract it, or to relieve the ship from those sudden and irregular lurches to which she is constantly exposed; and I have no hesitancy in saying, that the testimony of mariners will agree with the deductions drawn. It should be remembered, that although the points delineated are invisible and moveable, having no visible resting place in the hull of the vessel; yet they represent forces that have a tangible locality in the natural world, and are an index to the destiny of those who break down the bulwarks of creative wisdom, and in defiance of nature's laws, rear others suited to their own notions. It has been conceded by men of science, that in arranging the proportions of ships suited to navigate the ocean, the stability is

the first consideration ; practical knowledge has added weight to the dogma, and with this two-fold evidence, or this collateral testimony, it has been rendered a truism, and should be so received. For general reference, it may be well to lay down certain rules with regard to the augmentation of stability under ordinary circumstances. Stability, thus circumstanced, increases as the cubes of the breadth, as by adding one-quarter to the breadth, we double the stability, and as a consequence, a capacity to carry double the sail, with but (under any circumstances) one-fourth more resistance. In every branch of mechanism, wherein proportions are recognised as the standard of utility, it is found necessary to assume one portion of the dimensions, in order to proportion the remaining parts to the first ; this course is quite as essential in marine and naval, as in civil architecture. In mercantile sailing vessels of the larger class, it is necessary to assume the depth from the base line to what is sometimes termed the top height, or the lower side of the plank shear ; two-thirds of which should be set apart for the immersed portion, and the line of separation may be denominated the load-line, or the greatest immersed line of flotation. Having thus determined the depth of the vessel, we are now enabled to give

a proportionate breadth to a given depth ; the depth of the vessel, as already designated, may be divided into four parts, and the quotient multiplied by seven, which would be $\frac{7}{4}$ of the depth. Thus, for a depth of 22 feet from base to plank shear, we have $22 \div 4 = 5\frac{1}{2} \times 7 = 38\frac{1}{2}$ feet, this would be a proportionate breadth for ships having a poop-deck and forecastle-deck, but without these, $\frac{3}{4}$ would be quite as good proportions ; in smaller vessels, the proportionate breadth increases, and will be delineated in a part of the work set apart for that class of vessels. Steamers require a greater proportion of beam than any other description of large vessels—two parts of breadth for one of depth have been found to be the most efficient that have yet been adopted. It must be quite apparent to the thinking man, that inasmuch as the centre of gravity of the engine, boilers, wheels, &c., is near the centre of motion, in addition to which, the vessel having less stability at the extremities than sailing vessels, demands a greater proportion of breadth to insure an equal amount of stability. In reply to this demand, it has been said, that the fuel was amply sufficient to restore the equilibrium of stability, and thus render the additional breadth unnecessary. But again, it should be remembered, that although a steamer

might, at the commencement of a voyage, be found to possess a sufficiency of stability, having the proportionate breadth of sailing vessels: yet, at the end of the voyage, she would possess much less, in consequence of the consumption of her ballast, apart from the objectionable features of artificial stability instead of natural, and the consequent loss of speed, to which ocean steamers are subject, by a heavy draft of water. Having considered the length and breadth suitable for ships and ocean steamers, we will now proceed to determine their length proportionate to breadth; whether the object be burthen or speed, a good degree of length will be found advantageous; $4\frac{1}{2}$ times the breadth for the length on load-line, or 5 times the breadth for the length on deck, are fair proportions; and should the smallest ratio of beam be selected, the length may be increased to advantage, both for stability and burthen. The author is aware, that the proportions of breadth already given, are rarely adopted; that 3 feet of breadth for 2 of depth, is very generally regarded as good proportions for freighting ships; he, however, challenges a comparison of the profits accruing for one year, of two ships of equal displacement, one having the proportions herein laid down, and the other having those in general use, even though the

dark and forbidding aspect of public opinion and popular prejudice stare him in the face. The merchant or builder may desire a knowledge of the weight of the ship he owns or builds; and as the process of calculating the weight of all parts of the ship, and every piece of timber, and every bolt, spike, tree-nail, &c., is tedious and complex, even with the aid of the hydrostatic balance, it will rarely be requisite to have more than an approximation to the truth. True, the builder may know the precise weight of his ship by knowing the displacement below the launching line of flotation; but when the ship is built and launched, it is too late to make alterations however desirable; by knowing the actual weight of the ship within a few per cent. before she is built, we proceed with more confidence in the prosecution of the work; by knowing the displacement of the ship below the load-line of flotation, and deducting her weight from the same, we have the displacement remaining for cargo.—Ordinary sailing ships, for freighting purposes, from 5 to 800 tons, weigh $\frac{1}{3}$ of their load-line displacement; freighting ships of 1000 tons and upward, weigh one-half of their load-line displacement; ocean steamers weigh from $\frac{1}{5}$ to $\frac{1}{3}$ of their displacement—this applies to such as are built by propor-

tions approximating to those already given; when these dimensions are not adhered to, they weigh more. Iron steamers weigh about one-ninth less than those built of timber. For an approximation to the displacement of sailing ships, multiply the three principal dimensions together, length, breadth and depth, and that product by the ratio, four-ninths, or one-half, as the case may require, the second product by the weight of one cubic foot of water, the last product divide by the number of pounds in a ton, the result will be sufficiently near to enable us to determine something in reference to the dimensions and shape, but is not to be relied on as sufficiently near to build by, unless we are indifferent as to the amount of displacement. The ratio given will not apply to ocean steamers, without immersing them too deep, as this description of vessels should not be immersed more than five-eighths of their depth of hold, and if they have more than a proportionate depth, nine-sixteenths of their depth of hold should be marked as their load-line, above baseline, beyond which, they should not go. In approximating the displacement of ocean steamers, the ratio may be seven-eighths. There is another rule that is sometimes used to ascertain the displacement of vessels: multiply the mean of the lengths of the keel and

between perpendiculars, by the area of the greatest immersed section, or $\otimes$ frame in square feet, and divide this product by 43 to 46 for a merchant ship—if the ship be full, take the smaller number. This rule is not a reliable one for ocean steamers, varying from 48 to 62. No rule can be made that may be deemed reliable for all descriptions of vessels apart from the calculation itself, or the several modes described and illustrated by the diagrams, viz., comparative weight or comparative bulk, with the aid of the hydrostatic balance.

Mr. Pook, naval constructor at Charlestown, Mass., has discovered an ingenious mode of determining the capacity of vessels; and its approximation to the actual displacement of government and ordinary freighting ships, renders it valuable: its ready application to such vessels as have had their displacement calculated, will enable the reader to test its accuracy. Adapted, as it is, to almost all descriptions of freighting vessels; very sharp vessels, and particularly our sharpest ocean steamers, are exceptions to the general rule, having a smaller displacement than the rule would give, owing to their having no dead rise, and an easy bilge. The rule is as follows: From 90° deduct the angle of the floor, or the degrees of dead rise; multiply by .0075 the

quotient is the decimal for capacity—multiply the length by the breadth, and that product by the depth, from the bottom of the garboard to load-line, and the last product by the decimal of capacity, and divide by 35, the quotient

is the capacity in tons. Thus assuming a ship to be 160 feet long, 35 feet wide, and from the bottom of the garboard to load-line 14 feet deep, with four degrees of dead rise, as in Fig. 6. Thus we have—

	Decimal of Capacity.	Length.	Breadth.	Depth.	Exponent.	Cubic feet per ton.	
90° — 4° = 86°	× .0075 = ,645	160 × 35 = 5600	× 14 = 78400	× ,645 = 50568	÷ 35 = 1444	capacity in tons.	

The principal, and perhaps the only difficulty in applying this rule as a standard of measurement, is its liability to evasion, (which is the most objectionable feature in the present law.) The load-line could not be marked a proportionate distance from the base-line or from the plank-shear, without exposing the law to the same amount of infractions the present one is. But, as a ready rule for general reference and approximating the truth, Mr. Pook's rule is doubtless without a

rival. After the actual displacement has been found, a very convenient method of obtaining the capacity will be found in the following: Multiply the length between perpendiculars by the breadth, that product by the depth from base to load-line, this last product divided into the whole displacement, and the quotient will furnish the exponent of the ratio of capacity, and will apply equally well to all descriptions of vessels.





CHAPTER II.

An Exposition of the Tonnage Laws—Their Deleterious Effects—Necessity of Change—Tonnage Laws of other Nations—Laws of Resistance—Laws of Propulsion.

Having endeavored to show that reliable proportions cannot be furnished apart from mathematical demonstration, we shall now proceed to show the deleterious effects of the Tonnage Laws upon the commerce of the United States. It has been a matter of no little surprise to scientific men in the old world, that a country like ours should continue in force laws so detrimental to her commercial interests as the existing tonnage laws have proved to be; nor is the surprise confined to the old world: our ship-builders have long witnessed its baneful effects, and nothing but an indomitable energy has saved us from defeat in our race with England for the ascendancy in building ships. The hoary, the venerated prejudices of their fathers has too much influence to allow the ship-owner to think for himself, in connection with a growing jealousy, lest the builder should foster his own interest, while marking out a course for the measurement of ships, more congenial to the spirit of the age, and, as a consequence, avarice has been permitted to riot without control. But I pause to give place to the introduction of a new era in the commercial world. The change that has taken place in the British Navigation Laws, and the consequent reciprocal change in those of the United States, has awakened in the two greatest commercial nations on the globe, a rivalry, that in less than five years will revolutionise the commercial world. Had the United States a code of tonnage laws worthy of the name, she would have nothing to fear; but with her present laws, actually inviting fraud, she has much to dread; the terms are now unequal, the odds are against us, and the ship-owner will soon find that it is not enough to have equally as good a sailing ship, and one that will carry as much per every ton of displacement as his rival, but that he must carry more, and sail faster, if he would successfully compete in this commercial race; this a ship with large topsides on a small bottom cannot do. We should remember that English ships are now built under the fostering influence of

the best code of laws on the globe, while we are building under those among the most heterogeneous; and although the great bulk of English ships may have been built prior to the alteration of her tonnage laws, yet these are not the ships that are to be our rivals. As the author has already stated in substance, the American has nothing to fear when his energies can be concentrated on a single point with the world combined in the race to wealth or fame. It is between the conflicting interests of successfully competing with his rival, and the amount of dollars supposed to be saved in tonnage dues by disproportionate ships; and if we are lost in this rival race, it will be found that we have foundered in the straits of avarice.

It is mortifying to witness in the shipwright the mere mechanic. It is, indeed, humiliating, to see the most prominent intellectual art in the catalogue, reduced to a mere drudgery.—In these days of competition and hard utilitarianism, it is not only a pure relief to the mind, but a source of high enjoyment to the man who has kept an idea constantly before him, and has followed it with a fearless and faithful heart. It is he alone who can look through the perspective labyrinths of futurity, to an era when nothing will be acknowledged beautiful that is not

true; when ships will not only be built with reference to utility alone, but measured by the same standard.

It cannot be denied, that our tonnage laws, as they now exist, have done more to clog the wheels of improvement in marine architecture, than everything beside; whether we regard them as the parent of legalized fraud, or as the fruitful source of premature graves, their deleterious effects are alike obvious to the thinking portion of the commercial world. While the present practice prevails, of accounting the one-half, or any proportion of a ship's breadth for the depth, it must be quite apparent that ships will be disproportioned, and, consequently, unfit for navigating the ocean; by a diminished breadth, and an increased depth, the ship-owner registers his ship at much less than her actual tonnage, and, as a consequence, that wholesome competition which in every other enterprise is the muscle of improvement, is rendered weak and inefficient. Mechanics finding their boldest thoughts and best exertions fettered by the onerous burdens entailed upon commerce, have partially lost the laudable ambition to excel, they once possessed, and, like ship-owners, seem to have forgotten, in their haste for the dollar, that our ships perform little better, or make a voyage in no less time across the

ocean than they did forty years ago. Startling as this announcement may appear, it is nevertheless true, that voyages of thirteen and fourteen days, from this city to Liverpool, by sailing ships, were as frequent forty years ago as they now are. It will not be denied, that there are ships owned in this city, that under the same circumstances in which the best voyages have been made, would, without doubt, perform the voyage within eleven days; but those ships are engaged in a trade over which the tonnage laws have no warping influence; I allude to the trade with China. The profits accruing from our commercial intercourse with that remote nation, is found to consist in the quick returns, rather than the bulk of cargo; hence, the reason why no notice is taken of the inducement to evade the provisions of the present law, and the results are, that Canton has already been measured as distant but seventy-five days from New-York; and the day is not far distant, when the time will be reduced to sixty. There is one feature in political science that teaches us that cheerful submission to law is only rendered when based on the principles of equity; when its wholesome provisions bear alike on all its subjects. This great principle, the glorious bond of union in this republic, will be found no less advantageous to our commerce than to our country. England, sensible of this, abolished her heterogeneous code in 1836, since which time her improvements have been without a parallel in the history of the commercial world. In framing a law that will equalize the burdens, and make competition a fair and laudable enterprise, making the ship something more than a mere floating warehouse, and at the same time a source of profit to her owners, without abridging her carrying properties in the least, but rather augmenting them; and, as a consequence, making her owners greater returns than they can possibly do under the existing code, and giving him an equal chance for the rewards of energy and enterprise with his English competitor under the reciprocal navigation laws; it needs but a glance at our geographical position to satisfy the incredulous, that the United States is destined to become the great theatre for commercial improvements, and that it only remains for her legislators to enact such laws as will cherish a spirit of emulation worthy of our favoured locality, and of the age in which we live, to place her far in advance of other nations in commercial improvements. The present mode of determining the tonnage of ships by law, is a powerless aid to science and emula-

tion, and no sophistry can make that right which common sense pronounces wrong. It only remains for our legislators to be true to the instinctive impulses that have prompted the extension of our commercial interest to the present time, and this monstrosity in commercial science shall be found only in the history of the past. Nature has afforded all the necessary aid; her laws furnish an axiom around which all may rally, and feel safe in the assumption that beauty and truth are commensurate qualifications. By this standard of principles, we are willing that the science of marine architecture should be weighed, and if found wanting, let the fallacious dogma of science in this seemingly complicated art, be blown to the winds. Let precedent assert her prerogative. Let ship-building stand as it has ever stood in America, without a basis of principles. Let the continued watch-word through the unmeasured vista of time be precedent. Let the mildew of hereditary knowledge brood over the genius of intellect until the march of science shall be downward and backward, instead of upward and onward. It is one of the wonders of this wonder-working age, to see the very heavens and earth bending to American genius, and every element of nature made subservient to man's comfort and convenience, while com-

mercial science, this universal alcahest, lies like a statue in the quarry. The science of building ships is kept in dwarfish imbecility by the onerous burdens entailed by legislation. It will be rendered at once apparent to the discerning mind, that to equalize the tonnage laws, it will be necessary to obtain the actual capacity, which may be shown in cubic feet, tons, chaldrons, or bushels—this mode is far preferable to that of regulating the tonnage by displacement or weight—were the laws based upon displacement, the vessel carrying iron would perhaps be loaded when but half full, while the vessel carrying cotton would scarce be loaded when she was full; thus, the dues of the one-half full would equal those of the vessel that had stowed a full cargo. The laws respecting the measurement of ships, denominated tonnage, originally implied the number of tons-weight a vessel might safely carry; hence, it will be readily discovered, that it has lost its original signification, and is not now recognised as a tangible medium, but as a fictitious balance. The rule established by the British Parliament prior to 1836, had long been discovered to be founded on erroneous principles, and often led to the most mischievous consequences. Under this pernicious system, vessels came to be built narrow and deep, and thus, not only less effi-

cient, but highly dangerous; and as early as 1823, a committee was appointed to devise measures for the relief of commerce from its deleterious effects; that committee recommended the measurement of the internal capacity, by taking the breadth and depth at each quarter of the length; but for some reason, no step was taken, and the subject slumbered until 1832, when another committee was appointed to consider the subject. In order that the committee might be put in possession of all the available information possible to possess, her majesty's government obtained from various places the modes of measuring ship-tonnage, and the following was drawn up from the documents transmitted, commencing with England:—

Divide the upper deck, between the afterpart of the stem and the forepart of the stern post, into six equal parts. At the foremost, middle, and aftermost points of division, measure in feet and decimals, the depth from the underside of the upper deck, to the ceiling at the limber strake. Divide each depth into five equal parts, and measure the inside breadths at $\frac{1}{5}$ th and $\frac{4}{5}$ ths (from the upper deck) at the two extreme depths, and at $\frac{2}{5}$ ths and $\frac{3}{5}$ ths of the midship depth. Measure the length, as above, at half the midship depth. To twice the midship depth, add the extreme

depths. To the upper and lower breadths, at the foremost division, add three times the upper and lower breadths at the midship division, and the upper and twice the lower breadth at the aftermost division, for the sum of the breadths. Multiply the sum of the depths by the sum of the breadths, and the product by the length, and divide this product by 3500, the result is the tonnage for register. In vessels with a poop, or a break in the upper deck, measure the mean length, breadth and height, multiply these together, and divide by 92.4, and add the result to the former quantity. In open vessels, the depth is measured from the upper edge of the upper strake. In steam vessels, the tonnage due to the contents of the engine room (the depth being considered at the midship depth, and the breadth at $\frac{2}{5}$ ths of this depth) divided by 92.4 is to be deducted. The relative capacities of ships are determined very nearly by this method. In France, the three measures of length, breadth and depth, are multiplied together, and divided by 94, for the tonnage. In single-decked vessels, the length is taken from the after part of the stem on deck to the stern post; the extreme breadth is taken inside from the ceiling, and the depth from the ceiling to the under side of the deck; in vessels of two

decks, at Bordeaux, the length of the upper deck, and that of the keelson, are meant for the length; but at Brest, Marseilles, and Boulogne, the mean of the length on the two decks, from the stem to the stern-post, is taken as the length; the depth of the hold, from the ceiling to the under surface of the lower deck, is added to that of the height between decks, and considered as the depth. The extreme inside breadth is taken as in single vessels.—At Bordeaux, an allowance is sometimes made for the rake of the vessel. At Boulogne, in measuring steamboats, the length of the coal and engine chambers is deducted from the length of the vessel, and her breadth is taken at the fore and after extremities of the same, the mean of which is considered as the breadth; the depth is taken inside of the pumps from the lower surface of the deck between the timbers. At Brest, measures are frequently taken with a string, although contrary to law, and an error of seven tons in the tonnage of a cutter has been the result. In Spain, three breadths are measured at the following places: 1st, at the mizzen-mast; 2nd, a few feet abaft the fore-mast; 3d, at a point half way between the two former.—The heights at which the breadths are taken at the above places, are, 1st, on a level with the deck; 2nd, on a level

with the upper surface of the keelson; 3d, at a level half way between the two former positions. To find the area of each section, the half of the sum of the upper and lower measurements is added to the middle measurement, and this sum is multiplied by the height of one above the other; then half the areas of the fore and after section is added to that of the middle section, and this sum is multiplied by the length which the sections are apart from each other, the result will express in burgos cubic feet the capacity of the part of the hold between the fore and after sections; and it still remains to add the spaces between these and the stem and stern-post: these are found, without any considerable error, by multiplying the area of the foremost section by half its distance from the stern post. The room occupied by the pumps must be deducted from the foregoing result, in order to obtain the fair quantity of space filled by the cargo. Having thus found the capacity of the hold of any vessel in the above manner, in burgos cubic feet, it is to be divided by 41,61.779 feet of burgos.—In Portugal, for single-decked vessels, the length is measured from the cabin bulk-heads to the fore-castle bulk-heads; the depth is measured from the upper surface of the keelson to the under surface of the beams; the extreme breadth

of the deck is considered the breadth; the continued product of these three dimensions will give the contents in cubic feet, which, divided by 57.726 gives the tonnage. In vessels having two decks, two distinct operations are performed, one for the hold, and the other for the middle deck; for the hold, the length is measured from the heel of the bowsprit to the stern-post; the breadth is the extreme breadth of the upper deck, deducting two feet; the depth is from the upper surface of the keelson to the under surface of the beams, for the middle deck; the length is considered as half of that of the hold, the other half being allowed for cabins, &c.; the breadth as before, and for the height to the under surface of the beams of the upper deck. The foregoing is the mode at Lisbon, but at Oporto, the length of the vessel is taken from the second timber at the bows to the stern-post, the breadth at the widest part, from the inside of each bulwark on the upper deck, and the depth from the upper surface of the keelson to the lower surface of the beams of the upper deck at the main hatch. If the keelson be more than the ordinary depth, allowance is made accordingly—and where there are two decks, the thickness of the lower deck is also deducted from the depth; the length is multiplied by the breadth, and the product by the depth; this product is then divided by 96, the number of Portuguese cubic feet contained in a ton, and the result is the tonnage of the vessel. In Naples, the vessel having two decks is measured from one end to the other over all; the length is also measured from the after part of the stem to the rudder-port under the poop; the mean of these two lengths is multiplied by the extreme breadth of the vessel. The depth is then taken from the bottom of the well to the lower surface of the upper or poop deck, and the above product being multiplied by this depth, and divided by 94, gives the tonnage. For single-decked vessels, the tonnage is found by multiplying the extreme length by the extreme breadth, and the product by the extreme depth, divided by 94, as above. In the Netherlands, the length is measured on deck from the stem to the stern-post; for the breadth, the hold is divided into four portions, and two measurements taken at each of these divisions—1st, across the keelson, on a level with the upper surface from ceiling; 2nd, the greatest breadth of the hold at each division; the mean of these six measurements is considered the breadth; the depths are taken at each of the foregoing points of division, from the upper surface of the keelson to the lower

surface of the upper deck, between the beams, and the mean of these three is assumed. The length, breadth and depth, are then multiplied together, and two-thirds of the product considered as the tonnage; but an allowance for provisions, water, cabin and ship-stores, varying from thirty to forty-five, is deducted from the depth before it is multiplied by the length and breadth. In Norway, the length of a ship is taken from the afterpart of the stem to the inner part of the stern-post, dividing the length of the vessel into four equal parts; the breadth is measured at each of these divisions. The depth of the vessel, from the under surface of the upper deck to the keelson, to be taken at the above three points of division; then multiply the length by the mean of the three breadths, and the product thereof by the mean three depths; the result of the foregoing is divided by 242.1-2, if there be no fractional parts of feet, but if there be, the calculation is made in inches, and the divisor becomes 322,767; the result thus obtained being the burthen of the vessel in woodlasts, of 4,000 Neva pounds each, to reduce into commerce-last, one of which is equal to 5,200 Neva pounds, it is multiplied by 10 and divided by 13. In Russia, the length of the keel is taken in feet, and multiplied by the extreme breadth of the sheathing, and the product multiplied again by half the breadth, and divided by 94, which gives the number of English tons. In the United States, if the vessel be double-decked, the length is taken from the forepart of the main stem to the afterpart of the stern-post, above the upper deck, the breadth at the broadest part above the main-wales, half of which is accounted for the depth; from the length, three-fifths of the breadth is deducted, the remainder is multiplied by the breadth, and the product by the depth: this last product is divided by 95, and the quotient is deemed the true contents or tonnage of such ship or vessel. If the vessel be single-decked, the length and breadth are taken as above; for a double-decked vessel, three-fifths of the breadth are deducted from the length; the depth of the hold is taken from the under side of the deck-plank to the ceiling in the hold; these are multiplied and divided as aforesaid, and the quotient is the tonnage. The foregoing is the government rule, but at Philadelphia and New-Orleans there is a mode of measurement called carpenters' tonnage. The Philadelphia rule for vessels with one deck—multiply the length of the keel by the breadth of the main-beam, and the product by the depth; divide this second product by 95. For double-decked vessels, take

half of the breadth of the main-beam for the depth, and work as for a single-decked vessel. At New-Orleans, the mode in use is as follows: Take the length from the stem to the afterpart of the stern-post on the deck; take the greatest breadth over the main-hatch, and the depth from the ceiling of the hold to the lower surface of the deck; at the main-hatch from the length deduct three-fifths of the breadth, multiply the remainder by the actual breadth and depth, divide by 95, if the vessel be single-decked, but if the vessel be double-decked, half of the breadth of the beam is considered as equivalent to the depth, and is multiplied accordingly.

The Tonnage Committee having embodied in their report the tonnage laws of all the principal commercial nations, the discrepancy is at once rendered apparent. They recommend in their report, as a basis for the new law, that the whole internal capacity be measured; which, being under cover of prominent decks, may be available for stowage. They have given a short and easy rule for determining the capacity, with such accuracy, that if the whole mercantile marine were measured by the new process, the total registered tonnage would be very little altered. But they recommend, that no ship already registered, shall be re-measured, unless at the request of the

owner. The accurate estimation of the tonnage of a ship is a very difficult problem indeed; and it is indispensable, that any system to be adopted in practice, be not very complex: for if so, it will either be wholly inapplicable, or it will be sure to be incorrectly applied. The relative capacities of ships are determined very nearly by this method, that is, within little more than four or five per cent. generally, though in extreme cases, the difference may amount to ten or twelve per cent.; this, however, is insignificant, when compared with the errors so common under the former rule. The divisor, by which the cubic content is reduced to tonnage, was adopted merely, that while the reputed tonnage of nearly all kinds of vessels would be corrected by the new rule, the total registered tonnage of the kingdom might remain unaltered: thus, virtually substituting capacity or cubic feet for tons, or internal for external capacity. By the new method, the dues paid on tonnage are proportioned to the capacities of the vessels; and as no advantage is gained in these respects by defective forms consequent upon disproportionate dimensions, a marked improvement in merchant vessels has followed the passage of the law in 1835. The author is disposed to look through the vista of perspective futurity to the period

when the commerce of the United States will be relieved from the present heterogeneous code. With a slight amendment, the English law would be well-suited to the wants of the United States. The clause assuming the vessels to have a poop, or half-deck, should read thus: "If any vessel have a half-deck, poop, or weather-proof house, above the upper or main-deck, or break in the main or upper-deck, &c." It is notoriously true, that almost every ship that is now built, and being built, has a house upon deck; and it is sometimes the case, that in the distribution of deck surface, direct reference is had to the evasion of the laws of this or some other country. Vessels have been built in this city, and so arranged, that at pleasure they could be converted from a bark into a brig; the object was the evasion of measurement of the length of the vessel, which was set down as extending from the bow to the end of the tiller; thus, by removing the mizzen-mast, and substituting a long tiller for a short one, before entering port, some advantage was gained, where such laws of measurement existed. It must be apparent to the discerning mind, that any mode of measurement other than the whole capacity is subject to evasion; that to set apart any part of the ship for passengers, stores, or even a galley for the

cook, is only equivalent to an extension of those accommodations. While we measure ships, and regard that measurement as a standard for the payment of dues, the whole capacity should be measured; but the author hesitates not to say, that the world never committed a greater error in commercial economy, than when they first determined the existence of a law for levying dues according to tonnage: be the law of tonnage founded on weight, dimensions, or capacity, in every case it operates as a check to the most important manufacture of the country. In order that any nation may have free exercise for its skill, capital and enterprise, that nation must not be bound by injurious laws. Our government, by continuing in force laws so detrimental to commerce, deprives herself of that aid so essential in the event of a rupture with a foreign power.—Our European packets possess every other qualification than that of proper dimensions for rendering efficient aid to what has been termed the right arm of our national defence. Our tonnage laws have a direct bearing on the dimensions of every vessel built in the United States having more than one deck. But the ship-owners proceed with caution, lest the magnitude of the mischief provoke national legislation.

Leaving the tonnage laws in the

hands of those that made them, we shall endeavor to analyze the laws of resistance.

A variety of theories have been promulgated by men of science, for overcoming what the author has, in common with his fellow-mechanics, called resistance; each in their turn producing what, in the projector's opinion, seemed to be the most tangible, the most conclusive. Some have absorbed nearly all the retarding forces into the power of inertia, and have lost sight of all other influences; others have computed various other opposing forces, and have assigned to inertia but a small place in the catalogue; some have even ventured to delineate the only proper shape, and to furnish proportionate dimensions, by deductions drawn from the planetary world for all vessels adapted to the purposes of commerce. But the reader, who is adding practical knowledge to the stock of information he may have gained from theorists, will discover, that neither the earth's path, or the path of any other planet, will furnish him with a stereotyped edition of shapes or dimensions; that there is a variety of influences known only to practical men, that retard our progress in navigating the ocean. The lubricity of the element we navigate, would lead many to conclude that friction existed

only in name; but who, among the mechanical portion of the commercial world, does not know, that by coppering a vessel, we increase her speed, or that by coating the bottom with varnish and black lead, we augment the velocity with the same power. These, with other facts in the possession of the commercial world, teach us, that although water is frictionless, itself considered, yet, when brought into juxtaposition with a floating body or vessel, friction forms a considerable part of the opposing force.

Resistance has, from time immemorial, furnished not only an extensive field for operative genius and skill in every age, but has also furnished the motive power for overcoming the same, and may emphatically be termed the main-spring in mechanics. The great Syracusan philosopher required but an amount of resistance commensurate with the friction of his levers added to the weight of the world, and he would have had a platform for his fulcrum. It may be regarded as an axiom, or a universal law, that action and re-action, when applied to solid bodies, are commensurate quantities. The laws of motion are deducible, and may be known under three general heads:—The first, an inherent property of matter called inertia, and known as that law of the material world, by

which all bodies are absolutely passive or indifferent to a state of rest or motion, and would forever continue in the same state, unless disturbed by some external force, commonly called resistance. According to this law, the heavenly bodies preserve their progressive motions undiminished in those regions which are void of all resistance; the same law would keep the boy's top forever in motion with an endless revolution, were it not impeded by the air, and the friction produced by its point on the plane on which it moves. A ball discharged from a cannon would forever persevere in its motion, were it not retarded by the resistance of the atmosphere, and the operating influence of gravity.

The second general law is found when a change of motion is required which must be proportional to the moving force by which it is produced, and the change will be made in the line of direction in which that force is applied; hence, it follows, that motion, thus generated, is in right line with a velocity equal to the degree of impulse, and the course of a body in motion can only be altered by a fresh impulse, and is then compounded of its own velocity and the impelling force; that is, the body will be either accelerated or retarded in the same or a right-lined direction, in proportion to

the compound force of the two impressions. In like manner, if a ship be sailing before the wind, the impulse is in direct line, and, as a consequence, the resistance to be overcome by the two fluids is absolute; and the resistance met by the ship in the fluid that sustains her, and through which she passes, is only equal to the resistance met by the sails, and communicated to the moving ship. If a ship be sailing before the wind, due east, if you please, at the rate of eight miles per hour, and a current setting to the north, at the rate of four miles an hour, the vessel is driven between these two acting forces compounded at the rate of nearly nine miles per hour.

The third law of motion teaches us that action and re-action are always equal and contrary; or the action of two bodies on each other, or on a third body remaining passive, is always equal, but in contrary directions. Thus, when a horse draws a load, the power of the horse is diminished, or the animal drawn back, with a force equal to that which sets the load in motion; for if the weight of the load be increased, until it is equal to the strength of the horse, it will remain at rest, though the whole force of the animal be in action. If a load-stone, and a piece of iron of equal weight, be suspended by strings near each other, the mutual

force or attraction between them will cause an equal action, and the two bodies will leave their respective positions with an equal impulse and velocity, and meet in a point equally distant from each. If the bodies be unequal, they will meet in a point, whose distance from the bodies will be reciprocally proportioned to the difference of the powers. If two floating vessels, of equal magnitude and density, and, as a consequence, of equal displacement, and, in addition, possessing an equal amount of resistance, be attached to each other by a rope, the vessels being at some distance from each other, a force applied to the rope in either vessel will mutually draw them together with an equal velocity, until they meet in a point equidistant from their first position; but if the amount of resistance be unequal, even though the magnitude and weight, or displacement of the vessel, be equal, they will not meet in a point equidistant from each other, but the vessel possessing the least amount of resistance will advance the farthest; and the comparative sailing qualities of vessels may be tested in port as well as at sea, provided the propelling power is equally well applied in both vessels. Thus, it may be readily determined which of two vessels possesses the greater amount of resistance, by placing them any dis-

tance apart, in smooth water, where there are no currents; then connecting them with a rope, and applying a force to one end of the rope on either vessel, a buoy being placed equidistant from each vessel, it will be readily determined which vessel arrives at the buoy first; the same possesses the least amount of resistance, or is best adapted to overcome the inertia at that line of flotation, and, as a consequence, that vessel would sail the faster, other things being equal.

As the whole doctrine of resistance in fluids is based on the equilibrium of the same, we shall here give a general view of the leading principles of this branch of equilibrated gravity in fluids.

Resistance comprises all the influences that directly and indirectly oppose our progress in navigating the ocean, and may be divided into its several departments; inertia being the first and most powerful. The power of attraction, although seemingly of a negative character, forms a large bulk of the resistance to be overcome in navigating our rivers. Attraction is the cause, power or principle, by which all bodies mutually tend towards each other. This universal principle may be considered as one of the first agents of nature in all her operations—the whole universe is gov-

erned by its influence—and yet, after endless opinions, some of its properties are still concealed in the bosom of nature. We clearly see the effects of attraction, and decide on its laws; but human ingenuity has not been able to penetrate its principles, or to fathom its essence. It was considered by that profound thinker, Sir Isaac Newton, as a power proceeding from bodies in every direction, which decreases in energy or effect, in proportion as the squares of the distance from the body increase; that is, at any given distance, it will be four times as great as at twice that distance, and nine times as great as at three times the distance, and so on in like proportion. The formation of the element we navigate, and of all bodies, arises from the adhesion or attraction of the particles.—Who, of our readers, has not often witnessed its effects upon vessels sailing beside each other? An inferior sailing vessel is enabled, by this universal law, to keep pace with her faster sailing rival for many miles, until, by some sudden freak, the superior sailing vessel is enabled to break the seemingly attractive charm, and, by increasing the distance, diminishes the attraction. Or, who has not often witnessed a rival steamboat, holding at a convenient distance a much faster boat, by the power of attraction in the fluid they

navigate? How often have our readers witnessed the effects of crossing a bar in a river, or of a near proximity to a shoal, or to the shore, on the speed of the vessel, and the effect upon the water in the increased disturbance, caused by the addition of this attractive power to the resistance produced by other of nature's laws. This law has different divisions, and in those divisions, different modifications. The principal attractive forces known in the material world, are, cohesive, electrical, magnetical, and gravitating; the former and latter are those which should form a branch of the science of marine and naval architecture, inasmuch as a very material portion of the absolute resistance met by floating bodies is found to be made up of cohesive and gravitative attraction. A few examples will serve to illustrate the connection existing between them: Cohesion is the resistance witnessed on attempts to separate bodies, and is most powerful in the point of contact, or where the particles touch; at a little distance it becomes considerably less, and when the particles are still further removed, the effect is rendered insensible; the ratio, as found by Newton, has been already given.

The cohesion of particles of small bodies may be shown by a variety of amusing experiments. Take two

musket balls, cut away, say one-third of the bulk of each, thus forming planes, which should be made even, or, as the carpenters would term it, (without winding,) press the two flat surfaces together, and twist the bullets as they are pressed with the fingers, the plane will, by this means, be worn perfectly smooth and even; the parts thus in contact will adhere, or be attracted by a cohesive force that will resist a power of near fifty pounds weight to separate them; by this means, the air is expelled from between the planes, and a greater number of parts or particles brought into contact; as the formation of bodies arises from the adhesion or attractive properties of the particles of matter. If the metal in the above experiment were perfectly free from porosity, and the planes perfectly level, or mathematically even, on joining them together, the parts in adhesion would be as firm and inseparable as any other parts of the balls.—The elasticity of the air which is contained in the interstices, consequent upon the inequality of the planes, is the power that is perpetually endeavouring to rend them asunder. The planes of bodies can adhere only when the power of the parts in contact is greater than the natural gravity, and the elastic power of the air contained between them; therefore, the cohesive force is proportional to the number of parts that touch each other. Plates of iron, or other metals, of small dimensions, may be made to cohere with such force as would require the united force of a number of men to pull them asunder. Experiments have shown, that plates, not more than two inches in diameter, have taken a force of 950 pounds weight to separate them. In such cases, the surfaces have been smeared with boiling grease, and then left to cool before the power was applied; the grease serves to fill up the pores of the surface, and bring a greater number of particles in contact with each other. This adhesive power, or property in the particles of bodies, is not occasioned or aided by the gravitating weight of the atmosphere; for it is found by experiment, that it requires the same weight to separate them, whether joined together in open air or in vacuo. The author has witnessed experiments of a similar nature producing the most wondrous results. This cohesive law governs the union of iron to iron, and of iron to steel, commonly called welding. It is well known, that when at a certain degree of temperature, or at what is called a white-heat, two pieces of iron may be brought together, and the fibres of one piece driven by the hammer into the pores of the other, and thus, the air is

not only excluded by filling up the pores, but the pieces are actually riveted together, and if the work is properly done, is as substantial as any other part of the material.

It is by the attraction of cohesion the particles of a fluid or liquid arrange themselves into a spherical form, and extend their influence through the same channel to all bodies with which they come in contact. If a piece of board be laid upon the surface of water when in a state of rest, it will require a power nearly six times as great as the weight of the board, to take it up perpendicularly. These, and many other facts which daily occur in the common occupations of life, serve to show the universal tendency of that corpuscular attraction which exists between small bodies, and which teaches, if we will be taught by the laws of nature, that the resistance met by vessels when operated upon by a propelling force, can be augmented and diminished in proportion as we adhere to, or depart from, nature's laws. The last example, of the board, will teach us that a flat surface meets with more resistance than a convex one; thus, the longitudinally straight-sided ship below water meets with more resistance from the water than one having a convex side, other things being equal; this is equally true of the ship having straight

section-lines on the flat of the floor or bottom. The example of the board may illustrate this principle still farther, showing that the board presenting a flat surface to the fluid, as a consequence, receives the impulse of attraction in a direction opposite to the force applied to lift it; and it must follow, that force directly applied, must be more effectual than force obliquely or diagonally applied, which the board, having a convex surface, avowedly represents. It has been stated, that the law of attraction has different divisions and modifications. The wonders of another department of this sovereign law may be seen in capillary attraction, through the medium of which, liquids ascend the contiguous surfaces of bodies. This term is generally used to denote the ascent of fluids through small pipes or tubes that compose a considerable part of the animal as well as the vegetable body. By these tubes, as various in their number as they are different in their capacity, nature conveys nutriment to supply the most distant branches of vegetation, where it could never arrive by the ordinary motion of fluids. The extent of the attraction is in proportion to the diameter of the tube, that is, those tubes which are the smallest raise the fluid to the greatest height, and the larger to a less height, in a reciprocal proportion.

When the earth receives rain on its surface, the fluid is attracted through all the internal and contiguous parts, and then absorbed by the roots of trees and plants, and carried from thence by capillary attraction to the most extended parts through the multitudinous pores contained in the trunk and branches. It is by capillary attraction that the flaming wick of a lamp is supplied with oil from the reservoir beneath. By a knowledge of the laws of attraction, we fancy we see the reason why A attracts B, or why B is compelled to follow the motions of A, when connected; but when two distinct bodies, not connected by any visible bond of union, are observed to approach one another, the phenomenon seems to assume a greater degree of mystery, from our being no longer able to perceive any mode by which the one body can act on the other. On reflecting, however, on the constitution of material substances, and considering that they are composed of distinct particles, which there are many reasons for believing are not in contact with each other, we may soon satisfy ourselves that there is, in reality, as much difficulty in conceiving how the different particles of a body cohere, or act on each other by impulse, as in conceiving how one body can be the cause of motion in another placed at a distance. A remark of Maupertius is in perfect keeping on this subject: that the manner in which the different properties reside in a subject, is always inconceivable to us. The mass of mankind are not astonished when they see a body in motion communicate its motion to other bodies; we are accustomed to the phenomenon, which prevents our perceiving in it anything marvelous. But philosophers will not readily believe that an impulsive force is more conceivable than an attractive one. What in fact is this impulsive force? How does it reside in bodies? Who could have predicted its existence before seeing the bodies impinge against each other? The existence of other properties in bodies is not more clear. In what way does impenetrability and the other properties become joined to extension? In these there will always be mysteries for us. It must not, however, be supposed, that because mankind are ignorant of the why and wherefore, that they are in reality without available knowledge of the laws that govern the material world. Philosophers, without any reference to the question, whether the power which produces that tendency is inherent in the bodies, or consists in the expulsion of an external agent—they regard it as one of the ultimate phenomena to which the analysis of

matter leads. Newton himself, particularly cautions his readers against supposing that there is really an attractive force residing in the centre towards which bodies tend, the centres being only mathematical points. It will doubtless be discovered, from what has been shown, that cohesive attraction forms a very material part of the resistance met by floating bodies, and that by a knowledge of, and a strict adherence to these laws, we are enabled to modify the resistance on vessels, and thus the advantages of science blended with practice, are made manifest, not only to the thinking-man, but to the casual observer. Mr. Russell, in his experiments, met with some results which are said to be of great value to practical men on the general problem of the resistance of a fluid to a solid body; a department of science of which the mechanical world is avowedly ignorant. The assumption, that the fluid impinging against a solid, or the solid against the fluid, were the same, or produced the same results, must be regarded as erroneous, and calculated to mislead the inquirer after truth; the solid impinging against the fluid, not only causes a greater elevation at the surface, but a greater disturbance, as a consequence beneath, of which the surface may be regarded as an index; that the difference, however, would be

much less, Mr. Russell himself, perhaps, would be willing to admit, when applied to vessels. The extreme lubricity of the fluid being frictionless, must of necessity materially affect any change in the application of force.—Mr. Russell discovered that the sum total of the resistance on the anterior part of a solid was found in the wave generated at the surface; hence, by this hypothesis, it was only necessary to find the force required to generate that wave, and the resistance was determined; here, again, we are shown the imbecility of science without practical knowledge. Had Mr. Russell known that vessels have been built in the United States so sharp, longitudinally, that at a speed of 20 miles per hour they did not generate a wave on the anterior part, he would have hesitated before launching that dogma upon the commercial world. It will appear manifest to the thinking man, that a vessel moving through the water must communicate a motion to the particles of fluid with which it successively comes in contact. The quantity of motion, therefore, communicated to the fluid, is necessarily equal to that which is lost by the vessel, and as a consequence is the measure of resistance. We cannot pursue the subject without giving an exposition of the prominent features of the attracting

power of gravity, and the pressure of air, as forming one of the component parts of the resistance to be overcome in navigating oceans, lakes, or rivers. The power of gravity gives the same velocity to all bodies, the truth of which may be tested by removing the pressure of the atmosphere. Every square foot of the surface of the ocean, as well as the earth, sustains a pressure of 2,160 pounds; this, as a consequence, in connection with gravitating and cohesive attraction, forms the resistance at the surface of the water; hence, it follows, that in the ocean, where neither the shore nor bottom has any influence upon the vessel, the atmospheric pressure forms a large portion of the resistance to be overcome by the vessel, apart from the cohesive attraction to the vessel by the water. It has been found, that at an angle of six degrees on the line of flotation from the longitudinal axis, or twelve degrees, with the two sides united, a wave was not generated at the highest speed that steamboats have attained in the United States; thus, it is plain, that on the anterior part, the resistance was within 2,160 pounds on every square foot of surface. It would be impossible to tell, however, what amount of resistance the posterior part of the vessel meets, while the method of modelling is left to the eye. No builder knows

whether the stern is adapted to the bow, or the bow to the stern; hence, it follows, that men of science, as well as men of practice, must forever grope in the dark, while every man follows his own whims in shaping vessels, without reference to a system of proportions in accordance with the laws governing the elements. Few men reflect, when modelling vessels, that the after end of the vessel is operated on when performing her evolutions, by a force that pulls directly aft, and that, while propulsion may be centered at one point, the resistance cannot be so located. It has been already set down as a truism, that a vessel moving through the water, communicates a motion to the same, and this quantity of motion is equal to that which is lost by the moving vessel. As vessels are now modelled without reference to a universal system of proportions, an approximation only can be made to the direct resistance; this may be determined on the anterior part of the vessel, and will answer for all ordinary purposes, in the following manner:—Multiply the area (in square feet) of the immersed portion of the greatest transverse section by 64²; the weight of one cubic foot of sea-water; multiply that product by the velocity in feet per minute; this product multiply by .4, .5, or .6, as the shape of the ves-

sel may require, the sharpest vessel requiring the lowest number, while the fullest vessels demanding the higher. An example will perhaps illustrate: Assuming the area of the greatest transverse section to be 892 feet, and the speed to be set down at fifteen miles per hour, we have 1320 feet per minute; thus, we have $1320 \times 892 = 1177440 \times 64\frac{2}{3} = 75141120 \times .4 = 30056448 \div 2240 = 13418$ tons, 138 pounds per minute, in adverse pressure or resistance. In order to have this resistance or pressure constant, the quotient or last number must be divided by 60, and we have the sum of 223 tons, 1420 pounds. But this amount of resistance is not wholly dependent upon the length or shape of the anterior part; the amount of the propelling power, and its application, have much to do with the resistance; neither does it follow, that the same mean angle of resistance on the interior part, with the same area of greatest transverse section or $\otimes$ frame, will attain the same speed with the same amount of propulsion. There is a definite amount of speed peculiar to every shape, and belonging to every shape, and beyond which, if forced, the vessel will not go without hazard. This principle, the author is aware, has not been received with favour; but he ventures to assert the possibility of its de-

monstration. It is a truism at once conceded, that an increase of speed is an increase of resistance, where no changes have been made to diminish the same; the resistance is found at the two ends of the vessel, and the power applied at or near the centre. Does it not appear quite manifest, that between those two powers the vessel may be rent into fragments? It matters not how strong she may have been built, the resistance pressing the vessel aft, and the power pressing forward, which may be increased to thousands of tons, will undoubtedly crush her if increased and continued. If proof were necessary, abundant may be afforded in the wholesale failures on steamboats, from which little appears to have been learned. There are steamboats running on the Hudson River, that will not bear the power they already possess, having a plumb-side, a hard bilge, and a flat bottom, at the same time having a large amount of resistance with a proportionate amount of power, they groan beneath a load too intolerable to be borne; the effects are both felt and seen, particularly in shoal water, where it not unfrequently occurs, that steamboats ground where there is from one to two feet more water than would be required to float them when in a state of rest. The proper form or shape

that will effectually obviate this discrepancy, will appear when it is known that the direction of the opposing influence, or the direction of the resistance, is met at right angles from every part of the immersed surface of the vessel; hence it follows, as an inevitable consequence, that vessels presenting to the action of the fluid a large area of flat surface, must, in proportion to the amount of that surface, have a large amount of direct resistance. It matters not as far as the action extends, whether the flat surface be on the side or under the bottom, the deductive results of experiments already shown have set this question at rest, the prejudices of public opinion to the contrary, notwithstanding; and were further proof required, we have only to point to the steamboat *New World*, having doubtless a greater amount of surface perfectly flat, than any other vessel near the sea-board of the western world. The direction of the resistance being at right angles from the outside surface, it follows, that the lines usually called water-lines, are improperly named, being only parallels to the line of flotation, and not lines of resistance. We do not mean that the water passes in the direction of lines running diagonally, as such course would indicate, but that the spherical motion of the molecules

are thus directed; and it must be clear to the thinking man, that a greater number of particles is set in motion on a vessel having a certain surfaced area of displaced fluid, and also a greater proportion of flat surface, than another having less, in other respects equal; those disturbed particles furnish a regulating medium at the stern of the vessel, and the extent of the disturbance determines the amount of speed, inasmuch as the vessel, by her shape, furnishes more or less cohesive attraction, and in the proportion of the cohesion is the speed of the vessel, the one having the least is found to be the fastest. This may, to many, seem paradoxical, inasmuch as some of our coasting vessels are remarkably fast sailers, and are perfectly flat, (hence, it seems to follow, that theory and practice disagree.) It will appear clear upon a moment's reflection, that all science in modelling vessels must be based upon the equilibrium of fluids, and all systems void of this inherent quality, must be spurious, and will eventually fall to the ground. It matters not in what direction the vessel parts the water; if a light draught of water is desirable, it may be obtained, as in the sloop of our rivers, or as in the steamboats. It is not the draught of water, or the angle of rise on the transverse section, that exhibits those

objectionable features so detrimental to speed, but the perfectly flat plane presented for attractive cohesion. Water, as has been observed, is a frictionless body, hence, the manifest deductive principle, were there no other, that at the least inclination or disturbance, the efforts to be relieved of the pressure are sudden and irregular, and that a sheet of water below its level at the surface cannot be held with a steady pressure when that sheet is in the form of a plane; this truth is recognised even by the school-boy, who plays with his boat in the gurgling brook. We have but to reflect that the direction of the forces are parallel on the flat bottom or side, and, as a consequence, it is as easy to move the sheet of fluid in one direction as another; hence, when relief is obtained from the pressure, all the molecules move in the direction of the least pressure, and as a consequence, the whole mass presenting the flat surface moves at once, and in the same direction, disturbing all the contiguous particles in a greater degree than they could under other circumstances have been disturbed; thus we can philosophically arrive at the reason why a steamboat having a greater area of flat bottom than another, will ground in shoal water, while another having less will pass clear, drawing more water than

the first; the attrition of so many molecules at the same time from the bottom of the vessel and the bottom of the river, causes an augmentation of pressure and disturbance; consequently, a commensurate loss of buoyancy, and the particles being unequally pressed, seek an equilibrium around the vessel rather than under her; whereas, had the vessel presented no perfectly flat surface, but the lines gradually rising in every direction, so that the direction of the forces would not have been parallel, it will be clearly perceived that the sheet forward of the greatest transverse section could not have found an equilibrium by passing aft without encountering a still greater pressure, inasmuch as the $\odot$ would be the lowest, and the surface forward would be more elevated than the sheet aft; but the great and universal law remains yet to be described. Inasmuch as all and every molecule of the fluid is spherical, and revolves around its own centre, so every molecule is least disturbed by appropriating a line of direction to itself alone; the motion of the molecules thus directed prevents their crowding on each other, and upon this, the whole theory not only of equilibrated gravity in fluids but of resistance rests; whether from cohesive attraction or from attrition, it all centres in this universal law. But again, we may follow

this subject farther, perhaps, with profit to our readers, by showing the results or the effects of an extensive area of flat surface on some of our steamboats; the bilge connecting the side with the bottom being short, the consequence is, that but a small sheet of water passes between the wheel and the edge of the flat of the bottom; this column (for water may be so considered, the pressure being the same horizontal as vertical) being pressed by the sheet under the bottom, and attracted by the water-wheel, gives place to the unequal pressure, and is filled up by the sheet below; and thus a continual current is formed while the wheel is in motion; and this current diminishes the buoyancy very materially, and that too, in the very place it is most needed, under the engine; thus, it will be perceived, that the means adopted to sustain the engine, support the vessel, and keep her in proper shape, are the very cause of her being broken-backed, and settling down under the engine: a fact too well known to be questioned, the cause of which has been sought only among the many false notions of the age. It is a well-known fact, that millions of dollars have been spent in this city alone on wholesale experiments on steamboats, on which the projectors have given the clearest evidence of their blind adherence to pre-

cedent, and that they had rather guess at what they want, even though they should be compelled to pay for the second effort thousands of dollars. All parties concerned in these wholesale blunders have become so accustomed to this mode of piecing and patching steamboats, that it seems to be regarded as unavoidable; and if a company or an individual is so fortunate as to obtain a boat that requires no alterations, they or he is congratulated on their success in securing the services of men who have guessed so near.—Science, or the principles of philosophy, seem to have been set aside altogether, as unworthy of the Anglo-Saxon race. Public opinion has been melted in the crucible of precedent, and moulded into a bundle of prejudices. Were steamboat companies to unite in this matter, and continue experimenting on the same boat, they might arrive at something tangible; but this would bespeak a want of knowledge that they are unwilling to admit.

Resistance presents itself to the mind of the mechanic in other forms, and is known by other names than those already enumerated. All the force opposing the vessel's progress is absolute resistance, whether met on the bow or on the stern. On sailing vessels there are two kinds of resistance that steamboats do not encounter: the

first is called lateral resistance, or the opposing force which the vessel presents to drifting to leeward, at right-angles, or at any other angle with her course. This resistance is unlike other retarding forces; and a vessel cannot be said to be a fair sailer unless she possess a proportionate degree of lateral resistance; inasmuch as a loss of lateral resistance amounts to a corresponding loss of speed; for it follows as an inevitable consequence, that all the propulsive power expended on the lee-way would be added to the head-way were the vessel to make no lee-way; in other words, were the absolute resistance converted into lateral, in a given time the vessel would be farther advanced in her onward course, the propulsive power remaining unchanged. It does not, however, follow, that the vessel having the most lateral resistance, has also the least absolute; it not unfrequently happens, that a large amount of both is found in the same vessel. The second and last denomination of resistance that is not peculiar to steamboats, and only applicable to sailing vessels, is consequent upon the leverage, and the inequality of the lines of immersion and emergence; that part of the resistance consequent upon the leverage would indeed be small, were the centre of the propulsive power in all cases in its proper loca-

tion; but when ships that draw an equal draught of water when leaving port, are found from one to three feet by the head at sea, we are led to conclude that the distribution of the propulsive power has been improperly made; the inequality existing between the lines of emergence and immersion is to some extent unavoidable, but as far as may be, they can be equalized with great advantage to the vessel.—Experiments have clearly indicated, that by rendering the mean-angle of resistance more acute on the anterior part, the greatest transverse section may be located farther aft, and the lines of resistance on the after-body swelled out to advantage for speed or stability. But this augmentation of displacement on the posterior, and a diminution on the anterior parts, should be distributed very differently from what has been usually witnessed. First, it is important that the resistance should be distributed as near equally as is consistent with the employment of the vessel, on every line of resistance below the line of flotation; the lines of resistance on the after-body may be filled out to great advantage below the surface of the water, and by so doing, we may materially diminish the constant strain aft that exists, consequent upon the resistance on the posterior part, when vessels are performing their

evolutions. We have but to look at the white foam that skirts the surface of the contiguous columns on certain parts of the line of flotation of ordinary modeled vessels, to learn from whence comes this after-tow; by filling out the after-body, we do not mean that irregular shape so characteristic of English ships under the old tonnage laws, taken from the stereotyped editions of English works on Naval Architecture; the ponderous buttocks would be removed, and an equal bulk placed in the part requiring augmentation: in a word, the displacement would be regulated to act in concert with the resistance.

A very popular mode of reasoning upon the subject of resistance is worthy of notice, not on account of its approximation to any standard of truth, as deduced from science, experiments, or daily practice, but on account of its predominating influence over the minds of young mechanics, who are beginning to think for themselves, and who will shine in the road to science, when unshackled from those venerated notions so prevalent in the commercial world. There is a striking analogy supposed to exist between the resistance to be overcome by the ship, and that met and overcome by the fish; hence, the reason why many vessels are propelled with the wrong end foremost, under

the false notion, that, because most of the various species of fish are largest near the head, and have their greatest transverse section forward of the centre of their length, it must necessarily follow, that the ship must be so constructed, and when the buoyancy or displacement is thus arranged, the vessel is best adapted to all the purposes of commerce. The author can discover no analogy existing between the ship and fish in their evolutions through the trackless deep. Were this fallacious dogma not set at rest by experiment in the scientific world, it would perhaps be worthy of more than a passing glance. A body, partly immersed, meets with much more resistance than one wholly immersed, at a corresponding speed; the body wholly immersed, displaces a volume of fluid, the magnitude of which is precisely the same as that of the body itself, while the volume of fluid displaced by the floating body is just equal to the entire weight of that body; and it necessarily follows, that a body wholly immersed, meets with the same amount of resistance at every change of position, which is not the case with vessels partially immersed; the ship must contend with the buffetings of two elements, while the fish knows but one, and that one always tranquil. But another difficulty, in addition to many,

presents itself—the ship should not draw more than half as much water aft as forward, and she should be much less buoyant aft, so that it will be readily perceived the analogy does not appear so great after all—the fish possessing also within itself the elements of impulsion. Under some circumstances the ship meets with more resistance from the wind than she would if wholly immersed, and propelled at a corresponding velocity; or the same amount of power applied upon a vessel wholly immersed, would produce an equal amount of speed, apart from the resistance of the water which would be found to equal the first. It is not unfrequently the case, that the power of the waves and wind is more than equal to all the power of a propulsory nature that can be brought to bear on a ship, while at the same time the resistance below the water partakes of no perceptible change, or is not increased. The resistance of the atmosphere has seldom been brought into the account when summing up the whole amount to be overcome, when it is remembered, that upon every square inch of surface a pressure is sustained of fifteen pounds, and some reference should be had to this part of the resistance, when modelling that part of the hull above the greatest immersed line of flotation.

The laws of propulsion claim our attention, and seem to be almost inseparably connected with resistance, as there can be no propulsion without resistance. The term, however, has no application to a body moving on a rigid plane. In its most comprehensive sense, it may be defined as being applicable only to such bodies as are sustained on a fluid, for the evident reason, that no body sustained on a rigid plane by the centre of gravity, can be moved without the application of an excess of power over that concentrated at the same. The law of motion, under such circumstances, would properly belong to another branch of mechanics. When force is applied to a floating body, it yields to the impulse, however feeble that impulsive power may be; if it be a continued pressure the body must move in the direction of the force applied, unless there be some countervailing power acting at the same time in an opposite direction; and the relative connection between the moving body and the impulsive power is the speed attained. Here, again, we see equilibrated weight in floating bodies, standing out in drastic contrast with equilibrium in the same body when on a rigid plane. Resistance increases under the same circumstances in proportion as the density of the fluid increases by which the float-

ing body is sustained ; and were it possible for the fluid on which a vessel floats to become of equal density with the earth, and at the same time occupy no larger space than when a fluid, the vessel, instead of being sustained by a portion, being immersed, would continue to rise until she would rest on the surface : under such circumstances, it would require a power more than equal to the weight of the vessel to move her, without the application of measures to reduce the friction. In solid bodies floating on fluids, the angle of surface in juxtaposition with the fluid itself, and area of such surface, determine the ratio of resistance on vessels or bodies of equal bulk. We have shown that motion cannot be imparted to a solid body in equilibrium floating on a fluid, without the application of external force ; but it does not follow that the impulse must be received in the direction of the motion thus imparted, for the evident reason, that the effect produced is at right angles with the surface or angle of the plane receiving the impulse, as shown in Fig. 7 ; hence, the reason why vessels can be impelled within a few points of the direction of the wind ; and were vessels' sails so arranged, that the right-angled impulsive power would be in the direction of the beam, the vessel could make no headway, hence, the reason why all vessels have their sails so arranged, that when filled by the wind (although braced up to the sharpest point) the impulsive direction is aft of the direction of the beam. It should be remembered, that whatever may be the angle which the direction of the wind makes with the plane of the sails, the only effective force of the wind on the sail is that part of the whole force which can be resolved into a direction perpendicular to the surface of the sails ; therefore, whatever may be the whole force of the wind, its effective force will vary as the angle which the direction of the wind makes with the sail, and as the velocity of the ship is in proportion to the effective force of the wind, it will also (all things else remaining unchanged) vary this angle—see Fig. 7. It is evident, that when the ship is under sail, the direction of its motion should coincide with the direction of the keel, inasmuch as the amount of resistance encountered on the immersed part of the hull is less when the ship moves in that direction than it is when the line of motion meets the ship obliquely ; all that part of the force of the wind which acts in any other direction than that of the keel, must be a hindrance to her progress, and tends to force her in a direction in which she will meet with an increased resistance

from the water. From what has been shown, this increased resistance or retarding tendency must necessarily occur under every circumstance of the action of the wind on the sails of a ship or other vessel, excepting in that under which the trim of the sail is in the direction of the beam, or at right-angles with the keel of the ship. From this exposition, the angle of lee-way depends wholly on the angle of the sail with the line of the keel of the vessel, without any reference to the velocity of the ship; and the whole question of equilibrium existing between the force of the wind and the resistance of the water resolves itself into the foregoing conclusion, assuming the wind to be invariable, and the velocity of the ship to remain unchanged. But as the variation in the force of the wind causes a change in the velocity of the ship, a consequent change takes place in the angle of lee-way, and no writer has ever been able to produce a tangible theory upon this subject; but the distance a ship falls to leeward of her course in any given time, may, with rare exceptions, be easily ascertained, and tables formed from actual observation for ships. In the open sea, the amount of lee-way made in a given time, may be measured by the angle of the ship's wake, with the line of her keel or a line on deck. When a ship is either approaching or leaving the shore, and her head is constantly kept at the same point of the compass, her course will be along the line of the lee-way, and by taking the bearing of an object on shore, we may, at the expiration of a stated time, take the angle again, and the difference between these two angles will be the angle of lee-way. But as the pursuit of this subject is less congenial to mechanics than to nautical men, we will pursue the legitimate subject of the article under consideration. The centre of propulsion should be located perpendicular to the centre of displacement, for the evident reasons, if placed forward of the centre of displacement, (it is like a fulcrum on a precarious foundation,) the bow yields to the pressure, and the ship is brought by the head; hence, the reason why so many ships lose their trim at sea when under a press of sail. The reasons almost universally assigned (when a reason can be given for crowding so much sail forward) are to prevent the ship from carrying too much of the weather helm; in other words, to prevent her strong tendency to come to the wind. The laws of leverage may be aptly applied to the sails of a ship. The centre of effort of all the sails (or, as the term will perhaps be better understood, the centre of propulsion) may, like the





fulcrum, be concentrated at a single point, and represented as sustaining all the forces tending to propel the ship; but like the centre of gravity, it is an imaginary axis, and yet it is the index which will faithfully exhibit any discrepancy of moment in the distribution of the propelling power.—Plate 1 is designed to illustrate one of the methods adopted in Europe among men of science, of locating the centre of propulsion forward of the centre of the vessel, longitudinally divided on the load-line of flotation; the plate is the representation of a three-masted fore and main topsail schooner, with the centre of propulsion $3\frac{1}{2}$ feet forward of the centre of load-line. Some European architects place this point a relative distance from the centre of displacement, which is an approximation to the true method of distribution. It will be observed, that not only the centre of the area of all the sail is distinctly marked, but that the centre of the surface of every sail is also marked; and by having the centre and the whole area of all the sails marked at their respective places, we are able readily to determine an equivalent to the whole. Or, we may adopt another course to acquire the same results:—Draw a line that may be regarded as the mean base of all the lower sails, and another, that may designate the

head of all the lower sails, and continue to do so alternately on the foot and head of all the sails, the lines running parallel to the first; now measure the altitude from the head of the royal to the foot of the lower sails, deducting the openings between the lines representing the head of one sail and the foot of the next above; the remaining altitude divide into equal parts, and draw ordinates or lines representing those divisions, setting down the length of those lines—half of the upper and lower lines only should be taken—add all those lengths together, and divide by the number of parts, and you have the whole area of sail, the centre of which is the centre of propulsion, or, as is sometimes called, the centre of effort. It does not, however, follow, that any number of square feet above this point will effect the same that an equal number will below, either on the velocity or the stability of the ship; for it must be at once apparent, that if the laws of leverage are applicable to the distribution of sail on a ship or other vessel, that the farther from the fulcrum, the less the weight required to accomplish the same purpose; hence, it is plain, that one square foot of the royal, the wind blowing with a given force, will not propel the ship with an equal velocity that the same surface under the same pressure would near

the hull of the vessel, for the following reasons : the power exerted on the sail aloft has a much greater tendency to careen the vessel, and as a consequence, her best sailing position is departed from. The advantage of lofty sails are, however, apparent from a knowledge of the fact that currents of wind are often felt above, that do not descend to the surface of the ocean.— But, although the same area of sail aloft has a much greater tendency to heel the ship, yet it must also be borne in mind, that the sails are much smaller aloft, and continue to decrease in size in proportion to their altitude ; and this principle should always govern us in the distribution of sail, as will be shown more fully in Chap. XII., on masting and sparring.

If a ship were a cylindrical body, like a tub, floating on its bottom or flat side, and fitted with a mast and sail in the centre, she would always sail in a direction perpendicular to, or at right-angles with the yard, and as a consequence, would make no lee-way ; but, being an oblong body, may be compared to a chest, whose length greatly exceeds its breadth, and being so shaped that a moderate force will propel her head or stern foremost, while it requires a very great force to propel her sideways with the same velocity. The lee-way depends wholly

upon the direction of the impulse, and the action of the wind on the hull and rigging, which augments the lee-way. Persons unaccustomed to attend to these things are apt to imbibe a notion that the velocity of a ship can have no sensible proportion to that of the wind. "*Swift as the wind*," is a proverbial expression ; yet, the velocity of a ship always bears a sensible ratio to that of the wind, and even very frequently exceeds it. Fig. 7 exhibits the philosophy of sailing by the wind. Many have doubtless wondered how vessels could sail partly in the direction from which the wind blows. It will be observed, by referring to the diagram, that the yards are braced as sharp as they may be to advantage, and that the wind is represented as blowing in the direction of nearly one point farther aft ; hence, it will be quite apparent, that the sheet of wind acting on the sail is wedging the vessel along, and that the direction of the force is shown by the dotted line which is at right-angles with the yard or sail : also, that the same line as before stated, must indicate the force as being aft of the beam, or the vessel can make no head-way. Much, however, may be gained by a proper distribution of the surface of sail, in order that one part or end of the ship may neither have more, nor yet less than the buoyancy actually

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1. *Journal of the American Medical Association*, 1997; 277: 1033-1036.
 2. *Journal of the American Medical Association*, 1997; 277: 1037-1040.

1. *Journal of the American Medical Association*, 1997; 278: 1039-1044.
 2. *Journal of the American Medical Association*, 1997; 278: 1045-1050.

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1. *Staphylococcus aureus* (ATCC 12228)
 2. *Staphylococcus aureus* (ATCC 12228)
 3. *Staphylococcus aureus* (ATCC 12228)

It is also interesting to note that the mean age of the participants in the present study was 20.5 years, which is slightly higher than the mean age of the participants in the study by Bickman et al. (1998), but lower than the mean age of the participants in the study by Bickman and Helwig (1999).

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1. *Phragmites* (common reed) is a tall, grass-like plant that grows in wetlands and along waterways. It is a native species and is often found in large, dense stands.

1997, 1998, 1999, 2000, 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010, 2011, 2012, 2013, 2014, 2015, 2016, 2017, 2018, 2019, 2020, 2021, 2022, 2023, 2024, 2025, 2026, 2027, 2028, 2029, 2030, 2031, 2032, 2033, 2034, 2035, 2036, 2037, 2038, 2039, 2040, 2041, 2042, 2043, 2044, 2045, 2046, 2047, 2048, 2049, 2050, 2051, 2052, 2053, 2054, 2055, 2056, 2057, 2058, 2059, 2060, 2061, 2062, 2063, 2064, 2065, 2066, 2067, 2068, 2069, 2070, 2071, 2072, 2073, 2074, 2075, 2076, 2077, 2078, 2079, 2080, 2081, 2082, 2083, 2084, 2085, 2086, 2087, 2088, 2089, 2090, 2091, 2092, 2093, 2094, 2095, 2096, 2097, 2098, 2099, 2100, 2101, 2102, 2103, 2104, 2105, 2106, 2107, 2108, 2109, 2110, 2111, 2112, 2113, 2114, 2115, 2116, 2117, 2118, 2119, 2120, 2121, 2122, 2123, 2124, 2125, 2126, 2127, 2128, 2129, 2130, 2131, 2132, 2133, 2134, 2135, 2136, 2137, 2138, 2139, 2140, 2141, 2142, 2143, 2144, 2145, 2146, 2147, 2148, 2149, 2150, 2151, 2152, 2153, 2154, 2155, 2156, 2157, 2158, 2159, 2160, 2161, 2162, 2163, 2164, 2165, 2166, 2167, 2168, 2169, 2170, 2171, 2172, 2173, 2174, 2175, 2176, 2177, 2178, 2179, 2180, 2181, 2182, 2183, 2184, 2185, 2186, 2187, 2188, 2189, 2190, 2191, 2192, 2193, 2194, 2195, 2196, 2197, 2198, 2199, 2200, 2201, 2202, 2203, 2204, 2205, 2206, 2207, 2208, 2209, 2210, 2211, 2212, 2213, 2214, 2215, 2216, 2217, 2218, 2219, 2220, 2221, 2222, 2223, 2224, 2225, 2226, 2227, 2228, 2229, 2230, 2231, 2232, 2233, 2234, 2235, 2236, 2237, 2238, 2239, 2240, 2241, 2242, 2243, 2244, 2245, 2246, 2247, 2248, 2249, 2250, 2251, 2252, 2253, 2254, 2255, 2256, 2257, 2258, 2259, 2260, 2261, 2262, 2263, 2264, 2265, 2266, 2267, 2268, 2269, 2270, 2271, 2272, 2273, 2274, 2275, 2276, 2277, 2278, 2279, 2280, 2281, 2282, 2283, 2284, 2285, 2286, 2287, 2288, 2289, 2290, 2291, 2292, 2293, 2294, 2295, 2296, 2297, 2298, 2299, 2300, 2301, 2302, 2303, 2304, 2305, 2306, 2307, 2308, 2309, 2310, 2311, 2312, 2313, 2314, 2315, 2316, 2317, 2318, 2319, 2320, 2321, 2322, 2323, 2324, 2325, 2326, 2327, 2328, 2329, 2330, 2331, 2332, 2333, 2334, 2335, 2336, 2337, 2338, 2339, 2340, 2341, 2342, 2343, 2344, 2345, 2346, 2347, 2348, 2349, 2350, 2351, 2352, 2353, 2354, 2355, 2356, 2357, 2358, 2359, 2360, 2361, 2362, 2363, 2364, 2365, 2366, 2367, 2368, 2369, 2370, 2371, 2372, 2373, 2374, 2375, 2376, 2377, 2378, 2379, 2380, 2381, 2382, 2383, 2384, 2385, 2386, 2387, 2388, 2389, 2390, 2391, 2392, 2393, 2394, 2395, 2396, 2397, 2398, 2399, 2400, 2401, 2402, 2403, 2404, 2405, 2406, 2407, 2408, 2409, 2410, 2411, 2412, 2413, 2414, 2415, 2416, 2417, 2418, 2419, 2420, 2421, 2422, 2423, 2424, 2425, 2426, 2427, 2428, 2429, 2430, 2431, 2432, 2433, 2434, 2435, 2436, 2437, 2438, 2439, 2440, 2441, 2442, 2443, 2444, 2445, 2446, 2447, 2448, 2449, 2450, 2451, 2452, 2453, 2454, 2455, 2456, 2457, 2458, 2459, 2460, 2461, 2462, 2463, 2464, 2465, 2466, 2467, 2468, 2469, 2470, 2471, 2472, 2473, 2474, 2475, 2476, 2477, 2478, 2479, 2480, 2481, 2482, 2483, 2484, 2485, 2486, 2487, 2488, 2489, 2490, 2491, 2492, 2493, 2494, 2495, 2496, 2497, 2498, 2499, 2500, 2501, 2502, 2503, 2504, 2505, 2506, 2507, 2508, 2509, 2510, 2511, 2512, 2513, 2514, 2515, 2516, 2517, 2518, 2519, 2520, 2521, 2522, 2523, 2524, 2525, 2526, 2527, 2528, 2529, 2530, 2531, 2532, 2533, 2534, 2535, 2536, 2537, 2538, 2539, 2540, 2541, 2542, 2543, 2544, 2545, 2546, 2547, 2548, 2549, 2550, 2551, 2552, 2553, 2554, 2555, 2556, 2557, 2558, 2559, 2560, 2561, 2562, 2563, 2564, 2565, 2566, 2567, 2568, 2569, 2570, 2571, 2572, 2573, 2574, 2575, 2576, 2577, 2578, 2579, 2580, 2581, 2582, 2583, 2584, 2585, 2586, 2587, 2588, 2589, 2590, 2591, 2592, 2593, 2594, 2595, 2596, 2597, 2598, 2599, 2600, 2601, 2602, 2603, 2604, 2605, 2606, 2607, 2608, 2609, 2610, 2611, 2612, 2613, 2614, 2615, 2616, 2617, 2618, 2619, 2620, 2621, 2622, 2623, 2624, 2625, 2626, 2627, 2628, 2629, 2630, 2631, 2632, 2633, 2634, 2635, 2636, 2637, 2638, 2639, 2640, 2641, 2642, 2643, 2644, 2645, 2646, 2647, 2648, 2649, 2650, 2651, 2652, 2653, 2654, 2655, 2656, 2657, 2658, 2659, 2660, 2661, 2662, 2663, 2664, 2665, 2666, 2667, 2668, 2669, 2670, 2671, 2672, 2673, 2674, 2675, 2676, 2677, 2678, 26

1. *Chlorophyll a* (Chl *a*)

THE UNIVERSITY OF CHICAGO

1. The first group of people who are interested in the results of the study are the researchers themselves. They want to know if the study was successful in achieving its objectives and if the results are consistent with their expectations.

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requires. It is not a little surprising, that to the present time nothing has been done in the United States towards systematizing the distribution of the propelling power in sailing vessels; but each builder carves out a path for himself; and among the many notions that grow into rank luxuriance among commercial men, none bears a more glaring resemblance to superstition, than those pertaining to the propulsion of vessels; hence, the reason of so much mysticism; each builder clings to his stereotyped notions with a tenacity scarcely witnessed in other matters. It would seem, that if experience was the great and grand palladium of success, (a quality claimed by its adherents,) that it would have done something ere this, towards making a reliable course, that will regard the form of the vessel as an invariable index in an arrangement of so much importance.— About the time the ship's decks are framed, the builder furnishes the owner with a sketch-draft, or the dimensions of the spars of the ship he is building for his approval; by this course, the responsibility is divided, the builder relieved, and the vanity of the owner flattered. All ship-builders do not, however, pursue this course, but some have one peculiar to themselves, supposing they know enough in relation to the subject before them, and without consultation, furnish the sparmaker with a schedule of dimensions. We shall endeavor, in its appropriate place, to show what is yet required to enable the ship-builder to exclaim—

Behold! the genius of mechanic's skill
Ploughs trackless furrows at her master's will,
As if endowed with artificial life,
To lash an ocean into angry strife!

CHAPTER III.

Importance of a Knowledge of the location of the Centre of Effort—Method of obtaining it—The Model, an American Invention—Its Advantages—Its Origin—Its complete Adaptation to our Wants—Instructions for making them.

In this, as in the former chapter, it will be found that a judicious union of theory and practice is necessary to carry the branches of which it treats onward towards perfection; the two must be united—cordially and harmoniously united; practice must not decline the assistance of theory, nor must theory disdain to be taught the lessons of practice. “There are many principles,” says Mr. Atwood, (a distinguished writer upon this science,) “deducible from the laws of mechanics, which it is probable no species of experiment, or series of observations, however long continued, would discover; and there are others no less important, which have been practically determined with sufficient exactness—the investigation of which it is scarcely possible to infer from *the laws of motion*—the complicated and ill-defined nature of the conditions, in particular instances, rendering analytical operations founded on them liable to uncertainty.” It is true, indeed, as the same writer remarks in another place, that, although all results deduced by strict geometrical inference from *the laws of motion* are found by actual experience to be perfectly consistent with matter of fact, when subjected to the most decisive trials, yet, in the application of these laws to the subject in question, difficulties often occur, either from the obscure nature of the conditions, or the intricate analytical operations arising from them, which either renders it impracticable to obtain a solution, or if a result is obtained, it is expressed in terms so involved and complicated, as to become in a manner useless to any purpose. Thus, the mathematician has thrown barriers in the path to knowledge on this science; bent on his purpose, he gives a solution to a problem, while he is perfectly indifferent whether the world can or cannot comprehend the same. And it is remarkable, in how many instances uneducated men have anticipated the soundest deductions of the most enlarged theories, particularly in the United States; so much so, that they have

become proverbial. It is one of the instinctives of *Genius* to mark out an independent course of action. The untutored savage, though a stranger to Newton's third law of motion, applies it to practical use, when he sets his canoe afloat by pushing with a pole against the shore, or by adding a momentum to his missile weapons, by gaining an eminence. The practical knowledge the builder of a canoe exercises, is obtruded on the organs of external sense by the hand of nature herself. The Indian found, for example, that a particular disposition of the sail of his little bark would give it greater velocity than any other; a change of position of his own body, or of a stone in the bottom of his canoe, would alike influence its sailing qualities. These to him would be maxims of great practical value; for, by the operation of this instinctive genius two objects were accomplished by the same movement; for, while he made a better distribution of the buoyancy, he also augmented the stability, and as a consequence increased the speed. Thus we perceive, that without the aid of science, man may be brought to the recognition of its fundamental laws, or to the discovery of this most important truth, viz., that stability is an all-important qualification.

The importance of natural stability

will be recognised when it is remembered that artificial stability cannot compensate its loss. But while many assent to the dogma, few indeed have given the subject that attention its importance demands. Ship-builders in the United States have had recourse to analogy for determining the proportions of this important property, which perhaps in ordinary cases may answer every purpose; but cases have occurred in which our most prominent builders have been left entirely in the dark upon this subject: hence the necessity of a rule of reference upon a subject of such vast importance. To illustrate the principles upon which the stability of equilibrium depends, it will be necessary to assume certain conditions from which we may be able to deduce tangible results. If a ship has been brought by any force out of her erect position, it is important that the circumstances be indicated by which she will again adopt it; this ability is very properly called stability, and the amount of effort exerted for the recovery of the erect position is the index showing the value of, or the amount of stability, and as a consequence, the greater efforts to maintain the erect position, the greater the stability of the vessel. It must be quite apparent to the most casual observer, that an addition to the breadth of a vessel adds to the stability.

But how much has been added to the stability by increasing the breadth one inch or one foot, are questions that the most experienced cannot answer from experience alone; he must have recourse to mathematical expositions, which furnish the basis of every intellectual art in the catalogue. It must be remembered that the whole theory of stability is embodied in the emergence and emersion of that part of the vessel in the immediate vicinity of the line of flotation—in other words, the vessel being careened, a portion of one side is immersed, while the opposite side is emerged; consequently, the power or effort exerted by the immersed side to push the vessel upright, and the leverage of the opposite side to pull downward the index, showing that power is increased or diminished by adding to or detracting from the breadth of the vessel, or by adding to or taking from the depth, and is all that is expressed in the solution of the problem of stability. We shall endeavor to give a clear and luminous exposition of this subject in all its bearings; and if the reader will follow us attentively, we think he cannot fail to understand this subject, which has perplexed mechanics in every age, and which may, with truth, be regarded as one of the most difficult problems in the science of building ships.

Suppose A. D. B., Fig. 8, to be the greatest transverse section or dead-flat frame of a vessel in the position of its stability; draw a vertical line through the centre of gravity of the section, and it will be found that in this line the centre of displacement or the centre of gravity of displacement is located, either above or below E., which represents the centre of gravity. Careen the vessel as in Fig. 9, and let F. be the centre of displacement; draw a vertical line from F. until it intersects the middle line D. C. at G., above the centre of absolute gravity E., at which point the whole weight of the vessel is concentrated, and as a consequence, the value of E. is the entire weight of the vessel. Before proceeding farther, we will examine the peculiar properties of M., which is found to be the point where the two lines of flotation cross each other, viz., the upright and the careened lines, and as a consequence, the efforts of the water to right the vessel are centered at F., in a vertical line from M., and operate at G. when the vessel is drawn aside from her erect position. E. works downwards in a vertical line, as from E. to L., and the pushing powers upwards; consequently these forces turn the body or incline the ship to right, when the power that careened her is removed, and she floats with stability. But if

The first of these is the *vertical* position of the body. The body is in a vertical position when the line of gravity passes through the center of gravity. The second is the *horizontal* position of the body. The body is in a horizontal position when the line of gravity is perpendicular to the surface of the body. The third is the *oblique* position of the body. The body is in an oblique position when the line of gravity is at an angle to the surface of the body.

the centre of gravity of the displaced water be at H, and the vertical H J meets G D between E and D, as in Fig. 9, then the pressure of the water acts upwards in the direction H J, and the weight of the body downwards in the direction E L; these forces will therefore have a tendency to turn the body still farther from its former position, and it floats without stability: this will be a state of *instantaneous* equilibrium.

Through F the centre of gravity of the displaced fluid, draw the vertical line F M G intersecting C D in G; the point G is called the meta-centre, or as we have denominated it, the centre of effort; it is evident from what precedes, that the equilibrium will be stable when G is above E, and *instantaneous* when it is below E.

To determine the centre of effort, let S (Fig. 10) be the centre of gravity of the body, E that of the displacement in the erect position of the vessel, and F in its inclined position, h , h' and R the centres of gravity of N L B, A L M and B L M C respectively. If through the point E we draw a vertical plane at right angles to the section N C A, and take the *moments* with reference to this plane, we have, if we represent the perpendiculars from h' and h upon E J by p and q .

$$MCN \times EH = MCBL \times RT + LBN \times p \quad (1)$$

$$ACB \times o = MCBL \times RT - ALM \times q \quad (2)$$

$$\text{From (2)} \quad MCBL \times RT = ALM \times q \quad (3)$$

$$\text{But} \quad ALM = LBN \quad (4)$$

Substituting (3) and (4) in (1)

$$MCN \times EH = LBN \times h \quad (5)$$

making $p + q = h$

$$\text{Whence} \quad EH = \frac{\text{vol. N L B}}{\text{vol. MCN}} \times h \quad (6)$$

If the distance ES = d , and the angle H P E = φ

$$SG = EH - d \sin \varphi$$

$$= \frac{\text{vol. N L B}}{\text{vol. MCN}} \times h - d \sin \varphi \quad (7)$$

Designating the weight of the vessel by m , the moment of stability will be

$$m \left(\frac{N L B}{M C N} h - d \sin \varphi \right) \quad (8)$$

The upper sign is to be used when S is above E, and the lower sign in the contrary case,

$$EP = \frac{EH}{\sin \varphi} = \frac{N L B}{M C N} \frac{h}{\sin \varphi} \quad (9)$$

the distance from the centre of displacement to the centre of effort.

We will now determine the analytical values of EH, EP, &c. If we suppose the floating body to be a little inclined, the plane of flotation AB is replaced by PN; these two planes cut by a vertical plane, give the section N L B: if we continue to draw parallel vertical planes, we shall divide the solid into an infinite number of elementary solids parallel to N L B.

If we take the common intersection

of the two planes NLM and BLA for the axis of x , and place the axis of y perpendicular to that of x , in the plane NL , the ordinates will be the perpendiculars NL , $N'L'$, $N''L''$, &c. If the angle φ be infinitely small, $AL = LB$, therefore

$$p = q = \frac{2}{3}y \text{ and } h = p + q = \frac{4}{3}y$$

The area of the section BDN is

$$\frac{1}{2} \sin \varphi \cdot y^2 = \frac{1}{2} \varphi y^2 \quad (10)$$

Multiplying this section by dx , we shall have for the contents of the elementary solid BDN $\frac{1}{2} \varphi y^2 dx$

$$\frac{1}{2} \varphi y^2 dx$$

and for its moment,

$$\frac{1}{2} \varphi y^2 dx \times \frac{2}{3}y = \frac{1}{3} \varphi y^3 dx$$

Hence

$$(11) \quad \frac{1}{2} \varphi \int y^2 dx = \text{sum of the elementary solids.}$$

$$(12) \quad \frac{1}{3} \varphi \int y^3 dx = \text{sum of the moments of the elementary solids.}$$

If we substitute these values in equations, (6,) (7,) (8) and (9,) and represent the volume of the displacement by V , we have

$$EH = \frac{\frac{2}{3} \sin \varphi \int y^2 dx}{V} \quad (13)$$

$$SG = \frac{\frac{2}{3} \sin \varphi \int y^2 dx}{V} - d \sin \varphi \quad (14)$$

$$EP = \frac{\frac{1}{3} \int y^3 dx}{V} \quad (15)$$

$$\text{Moment of stability} = m \left(\frac{\frac{1}{3} \sin \varphi \int y^3 dx}{V} - d \sin \varphi \right) \quad (16)$$

If we suppose dx to be finite, and that the vertical planes parallel to ACN are equidistant from each other—the ordinates being y_1, y_2, y_3 , &c.,

$$EH = \frac{\frac{2}{3} \sin \varphi (y_1^2 + y_2^2 + y_3^2 + \dots) dx}{V} = \frac{\frac{2}{3} \sin \varphi \sum y_i^2 dx}{V}$$

$$EP = \frac{\frac{2}{3} \{ y_1^3 + y_2^3 + \dots \} dx}{V} = \frac{\frac{2}{3} \sum y_i^3 dx}{V}$$

$$\text{Moment of stability} = m \left(\frac{\frac{2}{3} \sin \varphi \sum y_i^3 dx}{V} - d \sin \varphi \right)$$

Hence, to calculate the moment of stability, we must know the distance from the centre of gravity of the vessel to that of the displacement; as it is inconvenient in most cases to determine the centre of gravity of the ship, the usual method in comparing the stability of different ships is, to suppose that the two centres coincide.

The calculation of $\frac{1}{3} \sum y_i^3 dx$ is to be performed in the same manner as in calculating the area of a plane figure, the cubes of the ordinates being used instead of the ordinates.

In the division of the ordinates in the upper water-line, there remain the two triangles raa' and whh' , which must be included in the calculation.

For such a triangle $\sum y_i^3 dx$ is equal to the cube of the base of the triangle (Fig. 13) multiplied by one-fourth of its height; for, if a be the base of the triangle, and b the height, then $a = \frac{1}{2}b$, and the middle ordinate is $= \frac{1}{2}a$.

	Cubes.			
a	a^3	1	a^3	Sum= $\frac{1}{3}a^3$ $\frac{1}{3}d = \frac{1}{3}b$
$\frac{1}{2}a$	$\frac{1}{8}a^3$	4	$\frac{1}{2}a^3$	
0	0	1	0	

$$\frac{1}{3}a^3 \times \frac{1}{3}b = \frac{1}{9}a^3b.$$

The following is the formula for calculating the distance to the centre of effort from the centre of displacement :

Ordinates of the upper water-line.	Cubes of the Ordinates.		
y_1	y_1^3	1	$1 y_1$
y_2	y_2^3	4	$4 y_2$
y_3	y_3^3	2	$2 y_3$
y_4	y_4^3	4	$4 y_4$
y_5	y_5^3	2	$2 y_5$
y_6	y_6^3	4	$4 y_6$
y_7	y_7^3	1	$1 y_7$
			S

Making,

$$y_1^3 + y_2^3 + y_3^3 + y_4^3 + y_5^3 + y_6^3 + y_7^3 = S$$

$$\frac{1}{3} \text{ distance between the sections} = \frac{1}{3} dx.$$

$$S \times \frac{1}{3} dx = \frac{1}{3} S. dx$$

Therefore

$$\int y_1^3 dx = \frac{1}{3} S. dx + \frac{1}{3} \overline{wh} \times \overline{hk'} \times \frac{1}{3} \overline{ra} \times \overline{aa'} = S'$$

Consequently

$$\frac{1}{3} \frac{\sum y_1^3 dx}{V} = \frac{1}{3} \frac{S'}{V}$$

for the height $\checkmark$ of the centre of effort above the centre of gravity of the displaced fluid.

$$\text{The moment of stability} = m \left(\frac{1}{3} \frac{S'}{V} - d \right) \sin \varphi$$

It is our province not only to delineate theory, but to show to what extent it accords with practice, and to make a *sirmark* where they agree.

In the theory of stability it is assumed, that the centre of displacement is the oscillating point,—that is true only at small inclinations,—the surface of the water, under some circumstances, becomes the fulcrum ; this discrepancy however does not affect the solution of this great problem. In the resolution of forces operating on a floating body that is not homogeneous, the influence of every force is increased or diminished at every change in the form of the line of flotation. The construction and properties of the curve that marks the path of the centre of effort, is a subject of geometrical reasoning, and considered as such, is liable to neither ambiguity nor error ; but on what grounds these properties are applied to measure the stability of vessels, or to estimate their security from upsetting when much inclined, has never been fully explained. Having already enlarged upon the theory, it may suffice to add, that when the ship's inclination has brought the middle line (which passes through the centre of the keel, stem and stern-post) parallel to the surface of the water, the centre of the absolute gravity again asserts its prerogative, and when brought vertically in line with the centre of dis-

placement, the ship is just as likely to upset as to come back; in a ship of proportionate dimensions the centre of gravity is low, and, (when properly shaped,) the centre of buoyancy high; the ship would then return to the erect position, even though the keel were above the surface of the water, when the force that careened her was removed. It is only those ill-shaped disproportionate ships that are thrown down on their beam ends; it is possible that any ship may be thus stricken down, but in nine cases out of ten they are such ships as have a high centre of absolute gravity, and a low centre of displacement. In looking into this important part of the science of ship-building, the mechanic will receive an additional stock of information by cutting a piece of pasteboard to the shape of the greatest transverse section, marking the lines of flotation, the centre of gravity and the centre of displacement as taken from the calculations; he will then discover the manner in which these forces perform their evolutions around the centre of motion; a pin or needle may represent the axis. It should be remembered that the area of the immersed surface or the solid of immersion must be invariable, notwithstanding the line of flotation is changing at every change in the inclination. It must also be remembered that as soon as the centre

of gravity emerges by the inclination of the ship, the centre of displacement becomes the oscillating point, and the distance between the centre of displacement and the centre of gravity will determine how much farther the ship will go without being able to return to the upright position. The centre of effort should not be less than eight feet above the centre of displacement, in order that the ship may have a sufficiency of stability for sea voyages. This applies to ships of from eight hundred to one thousand tons burthen. There can be no invariable rule given that will apply to all sizes and descriptions of vessels. The centre of displacement, however, will regulate the centre of effort, and is an index that will exhibit any discrepancy of magnitude in the ship's proportionate dimensions. In the United States the proper location of the centre of this particular force is seldom if ever thought of, while in different parts of Europe among men of science it is seldom forgotten, and is found within certain prescribed limits, which multiplied by the height of the load-line above the base, will furnish a medium as well as the extremes beyond which it should not be placed vertically; its longitudinal limits are equally well defined. The vertical maximum distance below the load-line is, $.4 \times$ by the height or multiplied by H ; the mi-

nimum distance below the load-line is $.3215 \times$ by H , and the medium distance below the load-line is $.3623 \times$ by H . For example, we assume the load-line of a ship to be fourteen feet above the base-line, we have then

Foot.	Maximum.	Foot.
$H = 14 \times$	$.4 =$	5.6
Foot.	Medium.	Foot.
$H = 14 \times$	$.3623 =$	5.0722
Foot.	Minimum.	Foot.
$H = 14 \times$	$.3215 =$	4.5010

The horizontal maximum, medium and minimum distances for the centre of displacement forward of the centre of load-line, may be found in the same manner. Let L represent the length of the load-line between the rabbets, and assuming the length to be 150 feet, we have

Foot.	Maximum.	Foot.
$L = 150 \times$	$.052 =$	7.8

forward of the middle of the load-line. This, it will be observed, is the forward extreme.

Again, let

Foot.	Medium.	Foot.
$L = 150 \times$	$.0175 =$	2.625

forward of the middle for the medium, and for the after extreme we have

Foot.	Minimum.	Foot.
$L = 150 \times$	$.01 =$	1.5

forward of the middle of the load-line for the centre of displacement. It will be perceived by this hypothesis, that vessels with their centres of displacement thus arranged, would draw more water aft than forward, (provided

their keels were of parallel depth;) a practice that has no basis in the principles of philosophy or experience.

The minimum distance, however, contemplates a parallel draft, or very nearly so. In modelling vessels without the draught, a knowledge of the location of those points is dispensed with, but not without hazarding more than any other than American ship-builders would be willing to. We shall now endeavor to give an example of the manner of arranging the tables of displacement and its connections, with other important points to be determined, in the calculations on the Ocean Steamer, Plate 2, and in doing this we shall adopt in practice that which we have endeavored to define in theory. There are several methods of calculating the displacement, but we shall adopt the parabolic system as being the most efficient that has yet been used, and adapting itself to the wants of Marine Architects, calculations by this system are very generally adopted by men of science in Europe, but their utility, with rare exceptions, has never been tested in the New World.

This system of calculating areas was first applied to the displacement of floating bodies by Chapman, the justly celebrated Swedish Naval Architect. In the annexed tables each water-line has a separate column of calcula-

tions, while the same line contains the same results in all the columns of the first division, or as far as the first numbers of reference extend. The first twenty lines contain the half-breadths of the frames or sections from the middle line to the several water-lines on which they are taken; and on their respective frames, the rule under this system requires alternate multipliers, the products of which are added together as on the twenty-first line, this sum is divided by three, and the quotient multiplied by ten, because the sections or fourth frames are ten feet apart. The last product is, as will be seen on the twenty-fourth line, the half area of the line on which it is taken aft of frame *p*. The vertical line of figures on the right of each water-line column are the products obtained by multiplying the number of the sections from frame 40, by the last product, and from which is obtained half the horizontal *moments*. The *moment* (whether horizontal or vertical) is the quantity multiplied by the distance of its centre of gravity from a fixed plane. Now, the fixed plane is section 40; the quantity is found in the products of the half breadths multiplied by the rule of alternate multipliers. The sum of the last column divided by three, and the quotient multiplied by the square of the section distance, which is ten feet,

equals one hundred; this last product is half of the horizontal *moments* from section 40 to frame *p*. In the right-hand column of the fortieth line of each water-line calculation, we have the half horizontal *moments* of the part forward of *p*, obtained, as will be seen by referring to the table in the same manner; this sum must be added to the amount aft of *p*. The half area of the water-line, to which the calculation belongs, is divided into the sum total of the horizontal *moments*, and the quotient furnishes the distance (in feet and decimal parts as explained on page 3) from section 40 to the centre of displacement of the same, (or the centre of gravity.) In order to obtain the centre of gravity of the keel we may proceed as follows: Length of keel, straight-rabbit, 213 feet, half area between rabbets siding direction or transversely .5, then we have this formula,

Length.	Breadth.	Square feet.
213	× .5	= 106.5

the half area. It then follows that the centre of gravity is 106.3 feet distant from section 40. Therefore, $106.5 \times 106.3 = 11310.3$ the half horizontal *moments* of the keel. The next calculation we shall endeavor to explain, will be that of obtaining the centre of the entire displacement from the half area of the water-lines, and their horizontal *moments*, as found in the middle

columns of the lower section of the tables, it will be seen that the rule of alternate multipliers is also used here, and the same course is pursued as in the upper columns. It will also be observed, that the calculations of the water-lines furnish only the half areas of the same, but from the lower section of the tables we obtain the entire displacement by adding those half areas into one sum, then multiplying by the alternate numbers and dividing the sum total of their product by three, the quotient being multiplied by the distance between the lines, which is 1.5 feet, gives half of the entire displacement, which divided into the vertical *moments* furnishes the altitude of the centre of gravity, or its distance below the sixth water-line. We next obtain the centre of the entire displacement longitudinally from the half areas and their cubes as shown in the lower section of the tables. The calculation for the centre of effort will be found on the right of the lower section of the tables. The problem of determining the location of this important point, we have endeavored to solve in all its bearings or relations; its altitude, like the length of a lever, determines the power with a given weight; and although to give the theory of the centre of effort, we are compelled to resort to the higher branches of mathematics, yet in its practical re-

sults we have, we think, made it perfectly intelligible to an ordinary mind. The half-breadths of the sections are taken on the load-line, beginning with section 40 as when obtaining the half area, and taking all the sections on the same line on which the half-breadth is shown; its cube is also shown, or the number multiplied by itself and the product by the same a second time, for example, 1728 is the cube of 12, thus $12 \times 12 = 144 \times 12 = 1728$, so with the half-breadths, in calculating the centre of effort. It must be observed in adopting the parabolic system not only for the ends of the vessel, but in calculating the displacement and centre of effort, that the water-lines, with the base-line and the number of ordinates, sections or frames, must be odd, so that the first and the last sections have the same multipliers; likewise in obtaining the altitude of the centre of displacement, it is important that there should be an even number of water-lines, which with the keel, will make the number odd. The general rule for finding the contents of surfaces and solids by the equidistant ordinate method, is included in this proposition, viz.: If any right line as *r w* Fig. 13 be divided into an even number of equal parts (which as a consequence makes an odd number of lines) *y y*, &c., and at the points of division be erected per-

pendicular ordinates, such as $a a, h h$, and so on, terminated by any curve, such as Fig. 13, or any other form, then if a be put for the sum of the first and last ordinate $a a, h h$, B for the ordinate marked $^2y ^4y$, &c., and C for the sum of $^3y ^5y$, &c., viz., the third, fifth, and so on, or the odd ordinates, excepting the first and last; then the common distance $^1y ^3y$, &c. of the ordinates being multiplied into the sum arising from the addition of a , four times 2y and twice 3y , &c., one-third of the product will be the area $a a, h h$ very nearly. That is,

$$\frac{a + 4 ^2y + ^3y}{3}$$

$D = \text{area, } D \text{ being} = \text{to } a ^2y ^3y, \&c.$
The same theorem will serve equally well for the contents of other surfaces, by using the section perpendicular to the axis or middle line, and is an excellent approximation for the area of all solids. The greater number of ordinates (or frames if you please) that are taken, the more accurately will the area or capacity be determined, as it will work equally as well on the inside of the vessel as the outside, and is sometimes used in cask gauging. The reason why the calculations in the tables do not extend to the forward perpendicular, and dispense with the calculations of a triangular part, is found in this fact; the several lines below the

load-line are shorter, and being of different lengths would require a perpendicular for each line, and as a consequence, the ordinates would require a corresponding change; it may be well to observe that section 40 was taken somewhat larger than the half breadth would require, in order that no calculation would be required aft of the perpendicular. It should be remembered, that the perpendicular is at the inside of the rabbet, on the load-line of flotation, and we feel safe in marking the terminations of this line as the only proper place for the perpendiculars of any vessel. We are aware that the perpendicular has been located higher than the load-line by naval architects, but the author is unable to discover any good reason for adhering to a practice that has not shown itself to have any claims to practical utility, however venerated by hoary traditions. The old perpendicular has no reference to the measurement for tonnage, capacity or displacement, nor is it the length on any of the decks, being placed at the termination of a sheer line at the height of the cross seam, hence it will be rendered apparent at once, that although two vessels might be built by the same moulds, and by the same man if you please, by elevating or depressing the sheer forward in one vessel, the other would be of a different length between those points,

PLATE 2.

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although the same model; but this is not all: the longest vessel between the perpendiculars is not always the longest on the load-line, and although a ship might be considered longer, and as a consequence be expected to sail faster, because she measures more between the perpendiculars than another, she would perhaps in truth be shorter than her rival. Having cleared all the obstructions that have a tendency to mystify this subject, we shall pursue the exposition of the centre of effort—the cubes of the breadths are multiplied as already explained in the first and last sections by 1, and the intermediate sections are multiplied by 4, 2, 4, 2, &c., alternately, the products are added, and their sum is divided by 3, the quotient is multiplied by 10, the distance in feet between the sections, this product is multiplied by $\frac{2}{3}$, and the last product is divided by the displacement in cubic feet, the quotient will be the height in feet above the centre of displacement, viz., 11.32 feet; we have also shown in another column the displacement of the next two feet above the sixth water-line, which would reduce the distance from the centre of effort to the centre of displacement to 9 feet. The draught of water would not be heavy even if the line above, or the line 11 feet above base were adopted as the load-line of flotation, being but 12 feet; this however would materially re-

tard her speed, which in ocean steamers is one of the most important considerations; the author regards an ocean steamer that is deficient in speed as scarcely less than a total failure, however many other good qualities she may possess. We shall doubtless be able to see at a glance what is the capacity of this steamer, at the twelve feet draught, the half area of the 9 feet line above base = 2817 feet, and the half area of the 11 feet line = 2957, which added together and multiplied by 2 feet, the distance between them, gives 11548 cubic feet, this added to 39211 cubic feet, the displacement between the 9 feet line and the base, gives 50759 cubic feet below the 12 feet draught, which multiplied by eighteen-seventeenths, gives the additional displacement for the plank, making the number of cubic feet 53745; this sum multiplied by five-ninths for the weight of the vessel, we have remaining nearly 30000 cubic feet for the entire capacity; this sum divided by 35, the number of cubic feet in a ton, we have 857 tons; if the draught of water were increased to $12\frac{1}{2}$ feet, the capacity would be increased about 85 tons, making in all 942 tons. We shall now show the manner of finding the ratio of the exponent of capacity for the several water-lines, and from the entire displacement; first, to find the exponent of the sixth water-line, set

down the length between the perpendiculars, and multiply the same by half of the main breadth, and divide the product into the half area of the same water-line, the result furnishes the exponent for that line; example—

Length.	$\frac{1}{2}$ Breadth.	$\frac{1}{2}$ Area.
218	$\times 18.08$	$= 4141.44 \div 2817.2 = .68$

which is the exponent of the sixth water-line, and the remaining lines may be obtained in the same manner. To find the exponent of capacity for the entire vessel below the sixth water-line, multiply the length between the perpendiculars by the breadth, and that product by the distance from the base to the sixth water-line; the last product, which is cubic feet, must be divided into the whole displacement below the sixth water-line, and the quotient is the exponent of capacity; example—

Length.	Breadth.	Cubic Feet.	Whole Displacement.	Cubic Feet.
218.5	$\times 36.2$	$= 71187.3$	39211.74	$\div 71187.3 = .55$

the exponent of capacity.

Did we deem it necessary we might show another mode of calculating displacement, but having occupied more than a proportionate space in our expositions of this subject, we deem it wholly unnecessary, and shall proceed in our efforts to furnish some information upon such other parts of this important fabric as have been set apart for this chapter,

Few, if any of those who have the reputation of being skilled in draughting vessels, can by any power of conception form a correct idea of the form of the vessel drawn in its rotundity, or if they possess this rare endowment, it is impossible to convey in language the same to a second or third party; in Europe, ship-owners as well as builders have found it necessary to learn and practice drawing, that they might be able to acquire a proper conception of the form of vessels from the same, and with the aid of a work on naval architecture many have become proficient in the art, while they really knew much less of shape in its rotundity than the operative mechanic in the United States, who, in obedience to his own notions, has whittled out his first model. It will be at once apparent to the thinking-man, that it is impossible to represent two curves in a single line, or to delineate the shape of a line in two ways without making two lines; the most profound mathematician will admit this, and still further, it is difficult to retain two shapes in the eye at the same time, in all their relative proportions. While the present practice is adhered to, of determining the shape we want by the eye, we can scarcely suit ourselves on a plane, or if we do on the draught we are not suited in the vessel, because she is not exactly what we expected.

This discrepancy in the mode can only be remedied by drawing a perspective plan, which must of necessity form a second drawing, the principal objection to which exists in the fact, that it is quite an extensive operation, and unless the work is performed in strict accordance with the laws of perspective, which pertain to geometrical science, a correct idea cannot be given; thus it will be perceived that the draught alone does not furnish an index to rotundity in ships, and although useful, and in many respects far more convenient, yet for the single purpose of delineating the form of a vessel by the eye, the model is incomparably its superior, and to its invention are we measurably indebted for much of our success in preserving an equilibrium against the conflicting interests that surrounded us. The history of commerce has witnessed no greater achievement than is furnished in this ensign of mechanical genius. By its use we have been enabled to wring reluctant laurels from surrounding nations, who have paid a just tribute to this proud emblem of American skill. That the model is completely adapted to our wants must be admitted even by the casual observer, when he discovers that every part of the vessel may be exhibited, all the proportionate lengths, breadths and depths, every line may be seen in its appropri-

ate place, it exhibits not only the form but a ready mode of obtaining tables for the loft, and is for the purposes delineated, to the draught, what statuary is to a written description of the physical man, the latter the shadow, the former the substance. But there is another particular in which the model exhibits its superior advantages over the draught, an expansion plan, or a vessel expanded on a plane for the purpose of showing the true shape of every plank (or for obtaining the spiling of every plank as if taken from the ship on a rule staff) cannot be furnished from the draught. There is not a work extant that contains a correct plan of expansion; it requires but a moment's reflection to discover, that if a sheet of tea-lead, or some similar substance, were brought around the exterior surface of a half model, and the lower edge cut to the base-line or side of the keel, the upper edge cut by the lower side of the rail, the ends being respectively cut by the rabbets, both forward and aft along the cross seam and quarter piece; the sheet being now flattened out, it would be discovered that the lower edge is not straight as represented in all plans of expansion by naval architects. Every mechanic at all familiar with the operation of planking knows, that by twisting plank the edges vary proportionately from a straight line,

and as there is no strake below water on the ship that has more twist than the garboard strake, it follows, that no strake has a greater departure from a straight line below water ; and although most of this winding is found at the ends of the vessel, yet it would be found that a straight-lined plank would require hard sets to make it seam to the rabbet on the keel, were the strake in one length ; the model makes ample provision for this discrepancy, and will furnish the shape required, as will be shown in its proper department. The *smi* (to use the familiar term) that increases so fast, as we ascend, is occasioned by diminishing the strake at the ends. We shall have occasion to resume this subject, and treat it more at length in a subsequent chapter, under its appropriate head.

The model, we have said, is a proud emblem of American skill, and to it are we indebted for much of our success. Models have been made in Europe as early as the middle of the last century ; but they were what would be recognized as the skeleton model, made of pieces representing the half frames, and are neither adapted to the purposes of building, or of exhibiting the lines of flotation. The invention of water-line models, like many others, was the result of mere accident. In the Eastern states, and in the British provinces,

men who were acquainted with the art of construction upon paper, made from a block the form of the vessel they intended to build, which was cut into several transverse sections ; those sections representing frames, were then expanded from the scale upon which the model was made, to the size of the vessel ; and frames were worked out to which harpens were attached, and the remaining parts, or intermediate spaces, filled in by making moulds to those harpens. In making one of those block models, the block was found to be too small to give the required depth, to which a piece was added, and when finished it was discovered that the longitudinal form of the vessel was shown by the line uniting the two pieces together. The question at once arose, if one seam was an advantage two would be a still greater ; and as early as 1790 water-line models were made for building purposes. The author has seen the model of a ketch, called the *Eliza*, 190 tons burthen, which was launched in the middle of June, 1794 ; this model was made in three pieces, by the scale of one quarter of an inch to the foot, 84 feet keel, 24 feet beam, and 9 feet hold, and may be seen in the rooms of the East India Marine Society, at Salem, Mass. This model has been preserved on account of the remarkable qualities the vessel possessed

for sailing fast; she was built by Mr. Briggs, the same builder who built the frigate *Essex*, at Salem. The first model made in this city was by David Seabury, which was soon followed by others. The *Ohio*, seventy-four, built for the Government, from a model made by Stephen Smith, of this city, then an apprentice to Mr. Eckford, was among the first vessels built from the model in the immediate vicinity of New-York; its advantages were soon appreciated, and the draught was laid aside, and has at length grown obsolete.

Before entering upon the responsible duties of delineating the construction of models, we shall render our readers a service by furnishing them with materials for reflection, from the framework of 30 years experience in building ships, by one whose opinion we have had occasion to notice in the first chapter. To an inquiry made of several of the builders of this city, the author received but one reply, viz., the eye is the text-book for modelling vessels.

The following letter we have deemed worthy not only of a place in this work, but of an inscription on the tablet of the memory of all such ship-owners or others as may suppose they know all that is worth knowing about building and masting ships:

NEW-YORK, January 20, 1850.

MR. J. W. GRIFFITHS:

“Dear Sir,—

“I am truly gratified to know of your intention of publishing a treatise on the subject of Naval Architecture. It is a work much needed. Your labors in this cause already merit the thanks of the profession, and I trust that your present undertaking, as it deserves well, so will it fare well at their hands, and of the public generally, whose safety and interests are so deeply involved in everything which has for its object the promoting of scientific knowledge in relation to this subject.

“I suppose there is no class of mechanics in the world who have labored at such disadvantages in the practice of their profession as ship-builders. Although ship-building, as a practical art, has been in existence for thousands of years, yet, as a matter of science, little or nothing has been done in its favor until quite lately. It is still true, that with the exception of those conflicting rules of tonnage, and that ill-advised dictation of owners, by which he is hampered and vexed, rather than assisted, each individual modeller has little else besides his own taste and eye to guide him. That the subject is capable of being brought under more general rules, like other departments of mechanics—in other words, that

the subject of Naval Architecture may be made a science as well as an art, no builder of experience has the least doubt. And ship-building can never be on a par with other practical professions until such is the case.

“Doubtless, here, as in other departments, practical men ought to look for a certain degree of information from the labors and studies of scientific men. The general laws of the resistance of bodies in fluids; the laws of motion; of the application of forces; the laws of gravity and dynamics, are fixed laws of nature, and should be as familiar to the ship-builder as the laws of heat and steam to the steam-engine builder. They should, indeed, be especially familiar to him, from the very fact, that the conditions and circumstances of their application are, in his case, so variable—almost infinitely so. This it is that makes the problem of modelling so uncommonly difficult.—The question, in each particular case, is involved (besides the preliminary conditions) with so many possible accidents, altogether beyond the builder’s control, and which must, nevertheless, come into the consideration of his model. When a mechanic builds a steam-engine, a sugar or a cotton factory, as soon as his work is put up it is fixed and done. But when a builder launches a ship, it is entirely

different; the thing is to be both at rest and in motion, liable to a thousand varying circumstances. His vessel is required to be strong, to be swift, to be capacious; to act well in sudden and rough weather, as well as in smooth; and to act well also upon the possible and often actual conditions of misplaced weight, loss of spars, and mismanagement or incapacity of those in whose hands she is. In addition to all this, she is often required to be previously modelled, in accordance with the fancy of some conceited owner, who, having made, perhaps, a single voyage in a ship,—and perhaps not even that,—thinks he knows more than all the builders in the world, and becomes ambitious of having his ships pass for his own, not only as owner but as inventor and builder also. Then, too, the ship-builder is not always at liberty to carry out his own idea as regards the sparring; but after submitting his list of spars, is often put to the mortifying necessity of making changes, which he knows must injure the action of the ship. Thus, not only his general art, but his individual reputation, is at the mercy of those who have no more than a mere smattering of knowledge. Of those who, while they think they know everything, are, in reality, so unskilled and ignorant as to be unable to detect differences in a

model sufficient to alter the character of a vessel.

"It is not ship-merchants, nor is it always ship-captains, that are possessed of that cultivation of the eye which is necessary in order to pass judgment at a glance, upon the merits of any particular model. This is a thing which is only to be acquired by the practice, not of *looking at*, or being ever so conversant in other respects with a ship, but of *making ships*. It may be safely said that his judgment of a model is not worth much, who cannot make a model. And those who are so unwise as to think they are qualified to control the mind of a builder in these respects, should learn to be modest enough to admit the truth of the above observation. They would find it vastly to their interest to do so. We shall never generally get first-rate vessels until owners and others shall be willing to remain in their own departments, and give builders the credit of being sufficiently informed in theirs. Let them give us the size, that is, the capacity, and the object of the vessel they wish to contract for, and then let us alone. This is all we ask, and we will pledge ourselves hereafter to give them better ships, without their assistance, than has hitherto been done with it; and the result will very quickly show it to be so.

"It appears to me, therefore, that

the main thing to be done in order to promote the science of ship-building, is to get rid of those unnecessary restraints which have been heretofore cramping the labors of builders, and preventing them from carrying out their own ideas in the practice of their profession. In the first place I would advise the advocacy, by your treatise, of an International tonnage law. Let the rule of measurement be that which takes in the actual capacity of the vessel. This is the only sensible rule, and the only one which will leave modelling free. How perfectly absurd is it, that a builder should, at this day, be subjected to a rule of tonnage measurement, which, if he were to follow it, would require the general proportions of his vessel to be the same that were in vessels at the time of Cromwell!

"In the next place, let builders be left free of the fancies and conceits of owners and others. Let them be supposed to know their own business best, and have no other requirements except the general terms of the contract, to hamper them. Then would they be on a par with other mechanics, to make observations, and to adopt the results of experience. I have said, that builders are to look to the labors of science for assistance. In many respects they are, but by no means to the

same extent, as other practical men. All science depends upon experiment; but the only *adequate* experimenters in this matter, are the builders themselves, together with the assistance which they derive from captains and sailors. It is not in the power of an experimenter, with cut blocks, in a pond of smooth water, and with artificially applied forces, to determine the best model for a given end. It is a very easy thing to build an ideal ship that shall be perfect; but to build a ship to go to sea, and carry cargo, and be exposed to the accidents of shore and ocean, is a very different thing. Scientific experiments upon land, of the kind mentioned, are certainly in their place, and have helped us to decide many important questions; and properly conducted will help us to decide more. But still the only adequate experimenters in ship-building are those who make and sail ships. The only sufficient elements in the experiment are with the ships themselves; and the only fair scene of experiment is the ocean upon which those ships are to sail, and to whose accidents they are liable. The great thing to be accomplished is, that ship-builders should be left free as possible to observe those experiments, learn from the results of them, and apply that knowledge to each successive model. Then will the art of building be, at the same time, the

science of building; and then will the interests not only of individuals, and of the nation, but the safety and prosperity of men, generally, be promoted to a degree not easily calculated.

“Concerning my views on sparring, for which you inquire, I am prepared at present only to say, that while I have some views on that subject which I have never yet been at liberty to carry fully into practice, I have not had that opportunity for experiment and reflection which would warrant me in expressing, at this time, those points in which I should vary at all from the common practice.

“With the best wishes for the success of your present undertaking, I remain, very truly,

“Yours,

“DAVID BROWN.”

The very first consideration, when about making a model from which to build a vessel, is the service for which she is intended. From this knowledge we determine the proportionate dimensions of the vessel to be built. In the concluding paragraph of the first chapter we have given suitable proportions for freighting ships; circumstances, however, must govern the builder in his adherence to, or his departure from those proportions: the altitude of the load-line of flotation has also been de-

fined. Should it be necessary to know the capacity or its approximate amount without knowing the actual displacement, we may be able to determine the exponent of capacity of any part of the model; and from this, by comparison with other models—the entire capacity and exponent of a corresponding part being known—we may deduce, in relation to capacity, all that may be necessary for ordinary purposes. For example, we will take the sixth water-line of the Ocean Steamer, Plate 2; length between the perpendiculars, 218 feet, half-breadth, 18.08 feet; these multiplied together gives the area in square feet of an oblong plane (square at the ends) with nothing taken off for shape; we may now take the half area of the sixth water-line, which, by referring to the tables, we find to be, 2817.2 square feet; divide the product of the dimensions into the half area, then we have the formula as shown on page 90. The term capacity is here used in the same sense as displacement, but more strictly speaking, it pertains to the interior part of the vessel for the reception of cargo. The unit, or 100, being all that can be obtained from the square box, consequently, we have lost 32 per cent., or parts of buoyancy, in providing a shape to answer our purpose at the sixth water-line. But we find that the whole per centage of buoy-

ancy lost on this steamer, is .45 per cent., or the exponent of the entire capacity is .55 per cent. In our expositions on the readiest mode of making models, we shall assume, that the eye alone is our text-book with regard to form; and having learned what we actually do want, we are prepared to make an effort to obtain it. The dimensions of the ship being known, and the altitude of the load-line of flotation above the base-line also known, we may divide the portion between those lines into equal or unequal parts, as occasion may require. If the ordinary mode is adopted, of making the alternate sections of cedar and pine, as in Fig. 5, the lowest piece should be of cedar, because it presents to the action of the file the largest surface, and is more easily made fair than pine. If the ship have but little rise on the floor, or as it is sometimes expressed, has but little dead-rise, the lower piece should be the thinnest, on account of having a line at the lower part of the bilge, which facilitates the laying off on the floor of the mould loft. There was a time when builders supposed that vessels must of necessity draw more water aft than forward, in order that they might obey the helm readily; and the difference was often made to appear in the first water-line, by making the lower piece thicker or deeper aft than

forward, by as much as the required difference was assumed to be. But this practice has grown obsolete, and a parallel draught of water is generally adopted; not, however, before the most abundant proof had been afforded, that the practice was without a basis in the principles of sound philosophy. In determining the altitudes of the load-line of flotation, it does not arbitrarily follow, that the model shall have no parallel pieces above this line; we may for convenience insert more; the effect of which is to reduce the thickness of the first sheer-piece. Nor is it absolutely necessary that the sheer-pieces should be alternately of cedar and pine. Some reference should be had to the disposition of the plank on the topsides of the ship, if it is designed to have a projection of the upper wale and thinner plank above, such as are usually called strings; the sheers on the model should correspond with such arrangements, in order that the sirmarks may serve as a guide in regulating the sheer on the ship. It will be seen that the proportions of depth for ships, as defined on page 43, are calculated from base line to the lower side of the plank-sheer, or as it is sometimes called, the covering board; and as a consequence, one sheer-line should be shown on the model at this height, measured on the greatest transverse section. It

may be farther remarked, in relation to former practices, that when ships were supposed to require a heavier draught of water aft than forward, they were no deeper, when measured, from the water-line to the rail forward, than aft. But, as we before remarked, all the difference of depth was beneath the surface of the water; and although the practice is not now adhered to among the prominent builders of this country, it is yet tenaciously guarded against innovations in many parts of the old world. The idea would be regarded as preposterous, of building a ship deeper forward than aft; but such is the present practice in New-York, where it was first introduced, and the results have proved most satisfactory; and ships have been built in this city, having from three to five feet of difference in depth at the ends, which adds greatly to their appearance, as well as to their performance. It will not be denied, that a ship cannot be placed in a more awkward trim, as it regards her appearance, than to appear to trim by the head; this applies to every ship of equal depth at the two ends. But this is not all; the bulkiest part of the bow is brought into immediate contact with the surges of every wave; whereas, had the same, or nearly the same, angle of resistance been continued above the load-line, and the flare of the

whole bow been raised some three or four feet, as the exigencies of the case might have required, the ship would have sailed faster, taken less water on board, and made better weather, in every respect. As we have set apart a portion of a subsequent chapter, to delineate the advantages and the readiest mode of sheering, we will follow the subject no farther: one or more pieces may fill the space between the lower side of the plank-sheer and the lower side of the rail; if the lower sheer-piece of the model have for its boundary lines a straight side below, and of any considerable thickness, the upper pieces may be made thin, and bent into the lower sheer; this will answer all practical purposes, and will save time, as a piece of parallel thickness and straight, is much quicker prepared than one of different thickness, and crooked. The whole number of pieces may be confined with dowels running perpendicular to the surface, or they may be screwed together in layers. As the model represents but half the ship, as a consequence, one side must present a plane, which must be perfectly fair; and upon this plane, the plan denominated the sheer-plan, is projected; this plan, which is the first laid off, (whether on the model, or on the floor,) is bounded by the base-line, which is the top of the keel, by the rabbet on the stem, and likewise on the stern-post, which is usually the inside of those parts, respectively; the upper sheer is regarded as the lower side of the rail; hence it follows, that the sheer-plan determines the length of the ship, and the heights at the several sheers and water-lines, or parallels to the line of flotation. Although the practice of regarding the rabbet as the inside of the stem and stern-post, has been adhered to, almost from time immemorial, yet it cannot be shown to be the most judicious arrangement that can be made in securing those important parts of the vessel. We shall give an exposition, in its proper place, of the utility of having the stem and stern-post inside, instead of outside of the ship. The materials for the model having been arranged and secured, either with screws or dowels; and the plane, representing the middle line, made perfectly fair, we may dress the opposite side parallel to the first setting off the dimensions, as being whatever half the beam of the ship requires to be in feet and parts, when applied to the scale by which the model is made. We next come to the location and shape of the greatest transverse section. Much has been written upon this subject, and there being still room for more, we shall not stop the progress of the model to discuss this matter, farther than to tell our readers

where we would place it, and give our reasons for so doing, after we have progressed farther with the work before us. We hesitate not to assert, that if nine ships out of every ten had their greatest transverse section shifted farther aft, and their centre of propulsion made to correspond with the change, that they would perform better than they now do; and entertaining these views, based upon the most reliable evidence, we would, on the model before us, place this section or frame on the longitudinal centre of the load-line of flotation, having assumed the ship to be adapted to freighting purposes; and as a consequence, would not advise more than from four to six degrees of rise on the floor, which is enough to give us a bilge, sufficiently easy not only for the stability of the vessel, but to prevent her from rolling; as the motion of a ship has less to do with the dimensions, and more to do with the shape, than the great bulk of mechanics and seamen are willing to admit; and as far as the stability of a ship is consequent upon the three principal dimensions, so far do our ship-owners, masters, and very many builders, believe the preventatives against rolling extend, and no farther. This is a contracted view of this important question, and teaches us that theory and practice have never held intercourse upon a sub-

ject in which the comfort of all who navigate the ocean is most intimately connected; but we pause not now to investigate this theorem, having an ideal model before us.

After having suited ourselves in the shape of the greatest transverse section, we may follow in the beaten track, and work off the model until it fills the eye, or suits our taste, by first moulding out the top sheer or lower side of the rail, as near as we can at present judge of what we want, subject, however, to such alterations as will present themselves, after the surplus bulk is removed; or we may pursue the course already described in finding the exponent of the area of load-line; and, by separating the model, adjust the form to suit our notion, and the area to the surface we require; the immersed part of the model may be again united to the topsides, or kept apart, until partially finished. If we adopt the method shown in Fig. 4, of obtaining the capacity or displacement we require, by the hydrostatic balance, or if we adopt that of Fig. 5, by comparative weight, we must keep the model free for separation at load-line. We have shown, in Chapter I., the more simple methods of obtaining the centre of gravity of displacement, as illustrated in Fig. 3; and without a knowledge of the locality of this point, we shall be unable to

adjust the propelling power, with any certainty of success, before the bottom is done, we may connect it with the topside, and make one part to suit the other. In shaping the topsides, we should remember that although a flaring bow causes the ship to have a light and lively appearance, yet it should flare but little, if any, as far aft as the foremast, on account of the fore-rigging, which will come in contact with the rail, unless the channels are wide, which is always to be avoided when practicable. Utility has also adopted the prevailing custom of forming the topsides aft, or the rail with more round than the wale; the object of which is, that the mizzen-rigging may be kept clear of the rail, with a smaller channel than either that of the fore or main, as the breadth and length of the channels should bear the same proportions to each other that the masts do, one to the other; hence it follows, that the mizzen-mast being the shortest, and the mizzen-channel the narrowest, the rail would become the channel, unless there was more round to the after frames on the head. This remark will apply to all the top hamper on the side of the ship, above the channels, which can scarcely be made sufficiently secure (without direct reference is had to a more elevated position in the distribution of timber in the frames) above the deck, or plank-sheer. A proper rake for the stem may be thus defined: enough above water to give life to the bow. Below water there is no absolute necessity for any rake; but enough to make the bow below look as if it belonged to the same ship as that of the bow above water, is not objectionable. We would not be as stringent in this matter, as many theorists have been in rearing restrictive bulwarks around the stem of a ship; by giving the exact angle of its rake, we believe that no definite angle can be given that will apply to every vessel; the whole bow has something to do with its boundary line, which the stem undoubtedly is; and we would add, that not only the shape, but the strength of the bow, has something to do with the rake of the stem. A lively light bow may be obtained, with a very considerable rake to the stem. Fifteen degrees is an abundance for almost any description of vessels. If we have a great rake to the stem, it inevitably follows that we have a great overhang to the bow, which tends to strain and hog the ship; all, or most of the flare we require, may be obtained by curving the knight-heads forward, which is an advantage in more than one respect; it not only adds to the lively appearance of the bow, but it sharpens the rail, and eases the whole bow above the plank-sheer, which ma-

terially relieves the ship from those surges, in a heavy head sea, which every mariner knows makes the strongest ship vibrate from stem to stern. This form of stem was introduced by the author, and exhibited at the fair of the American Institute in 1842. It was not, however, well received at that time, but has since been regarded as an improvement, and adopted as such. Upon the proper rake for the stern-post much has been written by scientific men, from which the mechanic might be led to infer, that the success of a ship depended upon the particular rake of the stern-post. This is not the case, the steering qualities of a ship are not consequent upon the rake of the post, but they are, to a very great extent, upon the manner in which it is connected with the ship. If the post be large, fore-and-aft, and is placed outside of a ship that is full about the load-line, she cannot perform to the entire satisfaction of those who manage her. It will appear quite manifest to the thinking man, that a ship, or other vessel, would steer with a much smaller rudder, were all but a sufficiency of caulking-wood placed inside of the vessel, and the remainder bearded off in the direction and with the lines of the vessel below water, as in Fig. 14. There are many vessels that have a stern-post quite large enough for a

rudder, were it hung on pintles. It does not require as much rudder as many suppose to steer a ship, if it be placed in the proper place. And we dogmatically assert it, that the aft edge of a large stern-post is not the place for a rudder. For steering purposes, the rudder should be placed at the termination of the lines of the bottom, and when this is the case much less rudder is required, particularly if the vessel have a fair swell of all the lines. Diagram No. 14, exhibits the present mode of uniting the rudder to the stern-post, outside of the ship, contrasted with that of connecting the rudder to the post, at the termination of the lines, and the motion of the contiguous body of water shows at once which is the most effective mode. The difference is so apparent, that a ship having a stern-post, as No. 2 of the same diagram, with an ordinary sized rudder, will feel her helm so quick, that a majority of good seamen would pronounce her a bad steering ship, while the only fault would be, *too much rudder*; and any manageable ship, under the proposed improvement, would not require more than two-thirds of the rudder-surface that she otherwise would, under the old method. And if the ship were modelled in accordance with the expositions already given, viz., by making the bow sharper, placing the great-

est transverse section at or aft of the longitudinal centre, and filling out the stern, as has been described, the ship would not require more than half the usual amount of rudder-surface. But we must look farther to see all the advantages accruing from this improvement; the security of the rudder itself should not be regarded as a matter of little moment. A large rudder, swinging at the mercy of a heavy cross-sea, is, at all times, to be avoided, even when the post to which it is attached is perfectly secure; but when we consider that the post itself, to which the rudder is attached, can hardly be made secure, in its isolated position, we must at once yield to this innovation into the stereotyped practice of our sires. And the very fact of ships having had their stern-posts started from their place, is sufficient to convince us that any measure that will render the post secure, and reduce the size of the rudder, must be regarded as an improvement, and should be at once adopted, for the better security of human life, in *confiding passengers*, and *those whose home is on the deep*.

We are aware that this does not accord with the cherished opinions of the commercial world; but we have fairly examined and proved this problem, and therefore risk nothing in giving it publicity. We wish, however, to be dis-

tinctly understood, that we do not mean, when we recommend a fullness aft, that *irregular swell* in the load-line, under the quarter, and a large skeig below; neither do we mean a fullness below water, by carrying the flat of the floor almost to the stern-post; but we mean a regular swell on all the lines below water, and the removal of the cumbrous buttocks that cause vessels to carry a weather-helm, by making so great a contrast in the weather and lee-lines of flotation. The full buttocks that are adhered to by the builders, with so much tenacity, are a great detriment to the ship in many respects, and no advantage in any; for, on the most feasible grounds that can be adduced, viz., stability and beauty, its disadvantages are but too visible, and the causes for their removal fairly gain the ascendancy. If stability be the object in view, we defeat our own purpose, for the reason, that no vessel can be stable that has an insufficiency of beam midships; and however much may be added to the ends, at or above the surface, that addition of buoyancy defeats the very object it was designed to accomplish. When at rest the ship is more stable, we admit, but when she is pressed forward, whether propelled by canvass or steam, the positive resistance along the bow, and the negative resistance on the quarter, cause a de-

pression midships, which makes the vessel roll, because of too much buoyancy at the ends ; whereas, had the ship an easier bow, and the irregular fullness removed from under the quarter, even with the same principal dimensions, she would have been steadier. But let the fullness be taken off the bow and quarter, and added to the breadth, midships, and the ship will steer easier, sail faster, and carry the same amount of cargo. One of the principal objections to this increase of breadth, is, that it makes a ship roll. This opinion is without a foundation in practical stability or sound philosophy, and we think it never would have been entertained by practical men, but for the invitation to evade the tonnage laws, by building narrow ships. It is a great mistake to identify the rolling of a ship wholly with the principal dimensions, (as we shall show in its appropriate place.) Another reason assigned for a full quarter, and a straight transom, is the appearance of the ship, or that it is an addition to her beauty, we do not so understand the import of the term *beauty*. We can give no other definition than the following: *fitness for the purpose, and proportion to effect the object designed*. The eye becomes familiarized with a certain shape, and habit causes us to think *that* the best we know the most about. The good steering quali-

ties of a ship is an item worth attending to, and is consequent upon the shape of both ends of the vessel. This we are aware is presenting the subject under a different aspect. To the after end of the ship has always been assigned the duty of regulating her steering qualities. However new the dogma, and however much it may conflict with the preconceived notions or prejudices of the age, the diligent inquirer after truth will find that resistance is a disturbance of the fluid ; and that the vessel having the most resistance, creates the greatest disturbance of the fluid. This, doubtless, is a conceded point, from what has been shown in a former chapter, viz., that the ship will draw more water, when the water is in a disturbed state, than when at rest. It follows, that the ship, passing the water to the rudder with the least disturbance, will steer with the smallest rudder. This will also be conceded ; and having yielded those two points, the third inevitably follows, that the bow has quite as much to do with disturbing the fluid as the after part of the bottom ; and that the stern should be adapted to the bow, and the bow to the stern, not by making the stern full, because the bow is full ; or by making the stern lean, because the bow is sharp ; but by observing the action of the element, and learning from what

nature and experience teach us, as well as theory and practice, both testifying in this matter, our reasoning will be conclusive.

It has been set down as a truism, that a full bow and a lean after-end were the best for speed, and every other good quality. We will not undertake to say this is not true; but we do say, that it needs qualifying; and we will also say, that the reverse is equally true. First, that it requires a longer after-end to equilibriate the fluid, when greatly disturbed, than when less, is quite apparent; and the short bow is undoubtedly the full one, and the long after-body is also the lean one.— But while this is partially true, it is strictly so, that a long bow, or a sharp bow, will perform in every respect, better with a proportionately short after-end, because the shape of the short after-end is better adapted to the restoration of the fluid, when less disturbed. And it is at once apparent, that the long bow is sharper than the short one; and, if properly formed, disturbs the water less at a given speed, or has less resistance at the same speed. It must be evident to the thinking-man, that a given amount of power, when applied to propel vessels, will counteract an amount of resistance equivalent to that power; and that as the resistance is diminished the speed

is increased with the same power. But the shape of the ship not only governs her speed, her capacity, and her theoretical stability, but it governs her practical stability. This problem, in the science of building ships, has been left to theorists for solution, who have committed an error that has proved fatal to the commercial world. By an ingenious mode of reasoning they have, upon false premises, drawn absurd conclusions; and mankind, ever ready to believe that which their interest leads them to desire, adhered to the dogma, without having even claimed the right of thinking for themselves. After having determined the dimensions of a ship, without reference to her practical stability, or her rolling properties, but with a view to her power to maintain an upright position under a press of sail in smooth water, which may be denominated theoretical stability, the index of which is found in the altitude of the *centre of effort*, as we have already shown, we should then depend upon the shape for the motion at sea, in connection with the proper distribution of the weights, which have much to do with the easy or uneasy motions of vessels. Two ships of the same principal dimensions, may, when at rest, have an equal amount of practical stability; but when at sea there will be a wide difference in the amount; not only

so, but the same ship may be so altered as to have her calculated stability decreased, and practical stability increased, as we have shown by reducing the fullness forward, and of decreasing the practical stability, by making a full bow and a straight side to the ship, as we have also shown ; or in another way, by keeping the extreme breadth below the surface of the water, as is often done to evade the tonnage laws. The whole problem of practical stability is found to be embodied in this truth, that the motions of ships at sea are consequent upon, first, the altitude of the centre of effort, and, second, upon the stability of the centre of gravity ; hence it will appear quite manifest, that if the centre of gravity has a vertical motion, it is not consequent upon the principal dimensions ; for if it were, homogeneous floating bodies, in shape as well as in density, would also have a vertical motion to their centres of gravity, which we know is not the case. For example, take a floating body in the form of a segar, cut it in two lengthwise, and it will be found, that although its centre of gravity is high, yet it is the stiffest shape that can be obtained with the same dimensions and area of surface. Take a smaller proportion of depth, which is the same as increasing the beam or the width, and the results are the same. We do not adduce this experiment to

tangibly settle any question in relation to stability, believing with the author of the letter found in this chapter, that the place for experimenting is the ocean. But we have used it as a figure to illustrate a principle that we feel safe in affirming, having ocular demonstration at hand to establish it on a larger scale. The steam-ship Georgia, doubtless the widest ship of her class (except the iron ship Great Britain) in the world, is one of the most easy vessels in her motions that floats, notwithstanding public opinion had marked her as an unmanageable ship, on account of her being three feet wider than another ship of the same line, the Ohio, and wider than either of Collins' line of steamers, which are much larger than the Georgia. The Cunard steamers are also much narrower, although longer and deeper. The America and Europa have but thirty-eight feet of moulded beam, and the Canada thirty-nine and a half feet, while the complexion of the practical stability of those ships is so well known that we need not enlarge upon their performing qualities. In this particular it may suffice to add, that the Georgia, with ten feet more beam, has more practical stability than any European steamer that has ever entered American ports. We have made our comparisons from steam-ships, because they are less vari-

able in the altitude of their line of flotation ; and because the two extremes were more fully represented in this class of vessels, than in freighting or sailing ships ; consequently, more information of a tangible nature may be obtained. No two sailing ships have ever been built, about the same length and depth, with ten feet of difference in their breadth, or at least we have never heard of so great a difference ; but although this wholesale experiment is practical *stability*, or the comparative rolling qualities of wide and narrow ships, has settled this vexed question, and solved the problem of proportionate dimensions with regard to this important quality in their performance, yet the author would not stop here, but take higher ground, and assert, that ships may be built so long and so wide that the motion of the sea will not be felt ; in other words, that they will neither roll nor pitch. We are aware, of the assumption, that in the oscillating motion of a wide ship, the gunwale or side rises higher on the windward, and falls lower on the leeward side, than in a narrow ship ; but is it not equally clear that there is the same amount of buoyancy on the lee as on the windward side ? and hence it follows, that there is as much power exerted to resist the tendency to inclination to the leeward, as there is to

cause the vessel to incline from the windward side. A steam-boat, with guards extending beyond the side, would be subject to a greater elevation on one side, and depression on the other, at the extreme breadth of the guard, with the same angle of inclination as another boat of the same breadth, and having no guards. This is quite clear, but were the boat itself built as wide as the guards, the case would be quite different. We have extended our remarks farther than we otherwise should have done, but for the discrepancy that exists between theory and practice, on this particular point. Scientific men have been led into a fatal error in their efforts to show from theory the advantages narrow ships possess in practical stability ; their mistake arises from their ignorance of the intimate relation between shape and the oscillating motion of vessels.

Commander Fishbourne, of the Royal Navy, in a course of lectures before the United Service Institution, in 1846, labored to establish in theory that which the whole commercial world has, to the present time, failed to prove by practice, in relation to the cause of transverse oscillatory motion in vessels at sea. This officer, evidently a man of science, makes his theorems appear quite plausible to the casual observer, who has not considered that the ground-

work of his theory is based on comparisons drawn from sailing-vessels, subject to a number of contingent circumstances which meet him at every stage of advancement, and which have not been brought into the account, either of which at once thwarts his path so completely as to obstruct his farther progress. He takes it for granted, that because vessels having a good degree of dead-rise, are generally wide, and as a consequence, have great inequality in the half area of the two lines of flotation—the windward and the leeward lines—it must follow, that their motions are uneasy; and because such shaped vessels require ballast, in consequence of the centre of gravity being high, their practical stability is thus reduced, and their inclination to roll greatly increased: but in the same sentence of his lecture he adds, that great stability prevents rolling. There is, doubtless, not a practical ship-builder, having had any amount of experience, who does not know, that a vessel with an increasing breadth above the light-line of flotation, and proportionately narrow near the base, is stiffer, or has more stability when immersed to the load-line of flotation, than another vessel having the same principal dimensions, with an increased amount of buoyancy at the base, and proportionately less at the surface of the water, or at the line

of flotation. It must be quite apparent to the thinking-man, that although the former vessel required ballast to bring her down to her bearings, in consequence of her having less breadth at the light than at the load-line of flotation, yet, as her breadth increased faster than the draught of water increased, her stability must of necessity increase in the same ratio; and farther, that all efforts to incline such a vessel from the erect position, must raise the centre of gravity like a clock pendulum, from its lowest position; and this resistance to inclination is greater in such shape than in any other, when the vessel is loaded, and less when light; whereas, the vessel with a hard bilge, long floor transversely, a plumb side, and having the same amount of displacement, with less breadth, will be stiffer than the other, when light, and less so when loaded; and the reasons are obvious, the fullness below when light furnishes a sufficiency of area to sustain the topside; but when this broad base is depressed by cargo to the loaded depth, at every inclination, however small, the efforts to trip the vessel are manifest, and the ship rolls until the influence of the centre of gravity, in its ascent, counterbalances the extra buoyancy, and she is again brought back not only to the erect position, but beyond it, when the same

freak is performed on the other side. While the vessel is at rest and upright, all is well, because the centre of gravity and the centre of buoyancy are in a vertical line, and the one directly operates on the other; but at the least inclination the influence is lost, and each central point has a separate interest to attend to. The operation is the same as with a man in the water, who would venture to place a bladder under his feet; it is evident, that while he kept himself erect, he would have a sufficiency of buoyancy to keep his head above water, but let his feet incline either way, and it would be impossible to maintain an equilibrium, for the very reason that he had too much buoyancy at the base, and too little at the line of flotation; but let him extend his arms, and hold a bladder in each hand, and he can maintain the erect position. Why? because he has a greater proportion of buoyancy at the surface, or at the line of flotation, than at the base. Upon this hypothesis the reason is quite manifest, why the steam-ship *Georgia* should roll less than other ships of her class, with ten feet more beam; and upon no other terms will theory and practice agree to assist each other in the demonstration of *truth*.

The stability of a ship does not depend upon the altitude of the centre of gravity, but upon the distance between

the centre of gravity and the centre of displacement, and the shape determines to a very great extent that distance. A ship that has an easy bilge, with four or five degrees of rise to her floor, and the flat perfectly straight, from the keel outward, with a good breadth of *beam*, the extent of which is at the load-line of flotation, will roll but little, and her roll will be easy and regular. In Fig. 15 will be found one of Commander Fishbourne's diagrams, by which he illustrates the action of the sea when ships are thrown upon their beam-ends. When passing up the face of the wave, the ship has to pass through an enormous arch before she arrives perpendicular to the other face of the wave, as from one to two, or from three to four, suddenly; the momentum is so great, that unless a vessel has a good breadth, or a good degree of stability, she is apt to lose her equilibrium, and fall over; and it is somewhat surprising that he should, under such circumstances, repudiate breadth. But we need not leave the mechanical world to find absurdities; men whose observation should have led them to a tangible basis upon subjects of so much moment to the mechanical and commercial interests with which they are immediately connected, are found adhering to opinions which have no basis in philosophy or experience; and adhere

to those opinions with an astonishing degree of tenacity, being able to give no better reasons for their opinions than *because it is so*, or *public opinion* so recognizes it, and it must be so.

We deem it unnecessary to pursue this subject farther at this stage of the work, but shall continue to fortify our position with tangible demonstrations from the several descriptions of vessels that may be found in the work. We shall again resume the making of a model, and pursue the work to its completion. The advantages of having the stern-post inside rather than outside of a ship, having been shown, we will next make an effort to exhibit the advantages of having the stem inside, or at least enough to enable us to beard it off in the direction of all the lines below water, not so much from the danger of having it started from its socket, (as the stern-post sometimes is,) but in consequence of the impression it makes in entering the water, which is of some moment in any description of vessel. This we are aware cannot well be accomplished without making the siding size of the stem larger from the base upward, which should be done, whether the suggested improvement takes place or not, the cutwater should have a firm basis, and when thus supported is doubly secure, not only in consequence of the

back having a broad surface against the stem, but by spreading the fastening we add strength and security; and every ship's stem should be sided larger at the head than the siding size of the keel, and this applies equally well to the stern-post; and some builders carry out this improvement, by making the post larger at the head than at the keel; the advantages are at once apparent, if we consider the post as it is now placed, outside of the ship, requiring more support than it can possibly receive, apart from the advantage of obtaining a large rudder-stock, without materially weakening the post, as well as furnishing a more firm basis on the deadwood and transoms. The rake of the stern demands notice. No rule should be laid down as an invariable one for raking the stern of a ship; twenty-five degrees from a vertical line, or from a line perpendicular to the base, is enough in any case for all practical purposes; the starting point, or the base of the stern, is the transom or cross-seam, when we have no transom, and the whole of this important appendage to the ship,—which has for ages perplexed and pleased the mechanical world,—will then rest upon this boundary line. Hence the importance of first defining its limits. The cross-seam derives its name from the ending of the diagonal and sectional lines on this line or

seam, where all the planks of the bottom which come within its limits terminate, and are met by planks running horizontal, and denominated the counter. Its proper altitude has not been defined by ship-builders themselves. It has been almost a universal practice to allow a counter broad enough at an angle of about twenty-five to twenty-eight degrees from a horizontal line, to cover the rudder with a strake of from five to six inches wide, upon which the arch-board is based, at an angle of about forty degrees from a horizontal line. The width of this, in some degree, depends upon the size of the ship, and upon the taste of the builder; the usual width will come within from twelve to fifteen inches, and above this the stern is projected. The continued practice of forming cabin-windows immediately under the deck-beams, and above the arch-board, has kept the cross-seam below its proper place; but in many instances, where the upper-deck does not extend aft, and the stern having false lights, or round ones, the arch-board might be raised, and as a consequence, the cross-seam would follow, and we thus would be enabled to effectually relieve the ship of those cumbrous buttocks that are the immediate cause of the weather-helm, by creating inequality in the inclined lines of flotation. There is, however, another objection to raising the

cross-seam, particularly at the quarter, made by ship-builders, which is equally groundless; were the quarter eased at the usual termination of the quarter-piece, the upper wale would lose its prominent features, by being twisted under the quarter. We are disposed to meet prejudice at every turn, or we would not have noticed this objection. It would scarcely seem possible that mechanics could be found in this age that would adhere in practice to what their judgment and experience condemned, because habit had made it appear less objectionable. We have already given a definition of *beauty*, which we think cannot be controverted. The last objection may be easily removed, by having no projection to the wale; and any vessel is better without the projection than with it. A flush side is least apt to get marred, and the ship is equally as strong: one or more colored strakes may be run by the seam, which should be quite as fair as though there was a projection. Before concluding our remarks on the stern, as defined by the model, we would add, that life and zest are imparted to the stern of vessels by raking them more at the quarter, and less at the centre, than builders usually do; and to the objections that may, and doubtless will be raised, viz., that the stern is not so strong, and that it is more expensive, as the twist compels

them to use narrower plank than they now do; we, in reply, first, as to the strength—the stern is stronger than the present mode, because it would rake less at the centre than they now do; and no one will have the hardihood to say that a great rake does not diminish the strength of the stern. But with regard to the strongest manner of building sterns, we think we shall be able to show, in its proper place, that the present mode of building sterns is not only less strong, but more expensive than another that has been introduced. In answer to the second objection to a twisting stern on account of the planking, we may remark, that by covering the stern with wide plank, we are compelled to line or sheath it,—which causes it to rot sooner than it would were it exposed to the air; the wide plank on the stern shrinks, and the seams become open, which cannot be caulked without marring the stern. With those general observations we will leave this part of the ship, and furnish some other general rules for the young beginner, in making models. While we adhere to the practice of determining by the eye the proper shape for vessels, the beginner, or the inexperienced mechanic, will find it to his advantage to put his model together with reference to more than one set of lines; by doing this he will be able to

discover new principles in modelling which he never thought of, and which, perhaps, never would have been brought to bear upon modelling vessels, without similar aid. Fig. 16 shows three modes of putting models together that will exhibit the manner and direction in which the resistance to motion is met on vessels; and while we may be able to obtain the tables for the loft, from a model thus put together, we may also improve our judgment in filling the eye, before we become so completely familiarized with a certain shape from which we cannot depart. It will be found, by a strict inquiry into the various opinions of those who model vessels, that there is very little originality of opinion with regard to shape; what is often termed experience, is rarely more than hereditary notions, handed down from father to son; and if the young man dare to form opinions from his own observation, which conflict with those of his sire, he is but too often branded as an addle-pated enthusiast, or a reckless adventurer upon the ocean of fame. When we say there is but little originality in modelling, we mean, in general terms, or comparatively so; for while in this, as in no other branch of mechanism, every person has formed an opinion of the requisite qualities vessels should possess, few, indeed, have based those opinions

independent of any expression from others. We have said, in a former chapter, that shape in ships is as distinctly traceable to the builder as lineaments are in the human face; hence the importance of looking well to this matter, before we are trammelled with a shape from which we cannot depart, even though we may be convinced of error.

The diagram, No. 1, of Fig. 16, referred to, exhibits the greatest transverse section of a vessel. The boundary lines are, the middle line, the shape of the frame, and a horizontal line meeting the two former at the lower side of the plank-sheer; the load-line is a proportionate distance, and the lines below the load-line are so arranged that the direction of the forces are very nearly represented; the lines running from the middle line, and pointing downward, are an approximation to what are recognized as diagonal lines, and show nearly in the direction of the plank on the bottom; but they represent something on the model of more importance; they approximate the direction of the rotary motion of the molecules, of which the fluid is composed—the lines varying from the vertical, or middle line, as we recede from the centre—and exhibit the direction of the pressure at different parts of the bottom of the ship; for example, the di-

rection of the pressure at the stem and stern-post, is at right-angles with the middle line, or parallel to the horizon; but as we recede from those points, or move aft from the stem, and forward from the post, the direction of the pressure is found to be at right-angles with the first line, numbering from the middle line. As we advance still farther towards the centre of the ship, we find the direction to be perpendicular to the second line; we still progress in our advances toward the centre, and the third line furnishes the same results as the former; the fourth answers a like purpose: those lines are but an approximation to the direction of those forces, as it is evident that nothing more could be given in advance, as the model, we must remember, is not yet made. In dressing the materials for a model of this description, we must bring all the stuff to a parallel width, which will bring all the pieces the same distance from the middle line, and from the base-line at each end; it will be discovered that No. 1 also forms, by the intersecting points, parallels to the line of flotation, or water-lines. The materials, or pieces, should be alternately of different colors, as shown in the diagram. No. 2 exhibits another mode of putting models together for instruction; and as the water-line, or the parallel to the line of flotation, can hardly be dispensed

with at first, we might find it an advantage to make twin models, or both sides of the ship, adopting for one side the mode represented in No. 1, and on the other side that of No. 2: No. 3 will also be found to elucidate the right-angled pressure principle, while at the same time it shows the favorite parallels to the line of flotation; the manner of putting together is less complicated than it would at first appear.—No. 1 must be put together in layers, as there are no parallels, but the layers for Nos. 2 and 3 may be dressed out in the usual manner, and glued together with the different colors, alternately, until we have a sufficient bulk to complete the model, or at least double the half-breadth; then, by commencing below, as No. 2, for example, taking the bevel of the diagonal from the middle line, and dressing a piece to the same, as shown in the figure, which will contain two colors, the same bevel reversed will answer for the second piece, that bevelling as much standing as the first does under; hence it will at once be perceived, that it is only necessary to slip the second layer up or down, until the opposite colors meet, and still the line is continued, if the materials are of equal or exact thickness; and without this is attended to we shall fail to accomplish our purpose, for at every line where the discrepancy in thickness

is found there will be a break. The middle line, it will readily be perceived, must be kept true, and a perfectly fair plane, and square from the water-lines from which to bevel: thus, by dressing our pieces to the bevel, and alternately sliding the layers up and down, we obtain the change in color, which exhibits lines running in different directions, and which are contracted and expanded in length on the model, when in its rotundity, as the lines are more or less acute; and thus the inexperienced become accustomed to measure angles of resistance by the eye. No. 3 is quite as easily constructed upon the same principle, and will show the diagonal line, by running lines in the direction of the points of the diamonds; and No. 2 will also exhibit the lines that illustrate the direction of the pressure, by running other lines, also intersecting the points, and the middle of the diamonds. No. 1 will, in the same manner, show the form of the water-lines. Although we have assumed, that the tables may be taken from models made in this manner, we having done the same, yet it is attended with more difficulty. The author's principal design in introducing and recommending them in the work, was to enable mechanics, who depend upon the eye alone for a guide, in modelling vessels, to have a perspective chart before them, and thus enabling

them to take the helm, and think and act for themselves, having first learned the laws of resistance, their nature, influence and extent, or in other words, the equilibrium of fluids, which covers the whole ground-work of resistance. In making models many persons suppose that it is necessary to have them made upon a large scale, and that by so doing they are better able to see all the discrepancies more readily than if the scale adopted were smaller; this is a great mistake, and for the reason, that the larger the scale the less one can see of the model at a glance, or without turning the head; if we desire to grasp the whole length of a ship with the eye, at one glance, without turning the head, we find it necessary to retire at a distance of perhaps ninety or one hundred feet, or until the angle from the extremes of length, to the eye, forms sixty degrees—as this is about all the eye can grasp with effect at once. If we now apply this angle from the eye, to the model made upon a three-eighths scale of a large ship, we will find that we are too far off to discover all the small defects, or all the unfair spots upon its surface, and if we draw nearer to the model, we must turn the head, and can only see part of the model at once; and when this is the case we lose part of the effect made by the bow, for example, while looking at

the after-end, and are prevented from properly balancing the ends of our model, or adapting one end to the other; hence it will appear quite manifest, that if the model were made upon a smaller scale, we could see the whole at once, and more readily discover the inequalities of one end when compared with the other; but the principal objection to models made upon a small scale remains yet to be examined, viz., that we cannot as readily discover defects, they being smaller than they would be on a larger model: this is true, if we measure both models by the same scale, but apply the appropriate scale to each model, and we shall find the full place of an inch on the one, is readily discovered to be an equal amount on the other. It requires some practice before we shall become sufficiently accurate to work altogether from a very small scale; but after having been able to determine what we want from the model, by the small scale, we shall, doubtless, adhere to it, and we will find no more difficulty in working from an eighth, or the tenth of an inch, than from three-eighths, or the half-inch scale. We must not forget, however, that the model must be perfectly fair, not only on all the lines, but in every direction; and if the lines do not furnish sufficient proof of the quality of our work, in this particular, we should

apply battens in other directions, transversely, diagonally, vertically, and in every other direction in which they may be applied; no matter what the shape may be, it should be fair, perfectly so: and if it is not so, it is little better than a failure, however good the shape may appear to be.

It is to be regretted that so many mechanics regard the model of a ship as a mere block of wood, like the casual observer who looks upon the marble in the quarry, without being able to discover the statue of the philosopher or the statesman. With such a glance mechanics will never be able to rend the veil that seems to hide nature's laws from their careless vision. But the man in whose mind's eye the surplus of the material itself melts away before his eager gaze, and leaves the ship in her identity, standing out in drastic contrast with the work of him who works only with his hands, we say it is he alone who will be able to approximate that degree of perfection only attainable through the medium of mathematical demonstrations. Hundreds of ships are modelled with but little regard to shape, like shoes made upon a last, the size determining their utility rather than the shape, and who that has worn them does not know, that unless the sole is the shape of the foot they will be uneasy, and wear away on one side

faster than the other; so with the ship, we may have good dimensions, or the ship may be all we require, as to size, but the bulk of the size may, like the shoes, be in the wrong place, and she will be uneasy in her motions,—a dull sailer, and hard on her spars and rigging, subject to more repairs than other vessels. There are some mechanics that will very readily assent to the truth of the leading feature in the science of Ship-building, viz., the *equilibrium of fluids*; but talk with them about modelling ships and they will deny its truth,—they will tell us how much harder the water presses below than at the surface,—what is the result of this increased pressure, at great depths, upon deep-sea leads, can-buoys, bottles hermetically sealed, &c., and adopt various methods to explain away the *equilibrium of fluids*. We have found men presenting claims to a knowledge of the science of Ship-building, and ship-builders themselves, in the ranks of such as disclaim experiments of a tangible nature, under their own observation, the results of which cannot mislead them, to follow the vague and indefinite theories of others. That water equilibrates in its own bulk is a truth that must not be questioned by any man who expects successfully to compete in building ships. It is not our province to follow theorists, and give

reasons which they themselves have not done, for this extraordinary pressure at great depths. There can, however, be little doubt that the water in itself is of greater density at great depths than near the surface. We shall not pause to inquire how far below the surface the boundary line may be found; it is enough for our purpose to know, that far below any depth immediately connected with navigating the ocean, the fluid presses everyway alike, and if more proof is required in addition to what we already have, let the incredulous man make a box of any dimensions he may find most convenient, or best calculated to settle the question; but let it be the same size at the top as at the bottom, make it tight, and set it afloat; mark its water-line, and put in ballast enough to settle it one foot, the weight of which must be known; continue to load the box until within the last foot, and he will find that the same amount of weight is required to displace the last foot that the first foot required; and this is the case within the range of all commercial operations; if we make the box thirty feet deep (which will cover the draught of water of any ship-of-the-line) we shall find that the results are the same. We have already given an exposition of this subject, but lest any of our readers should suppose that we advocated more breadth and less depth in ships, on account of the increased pressure on a heavy draught of water, we have given a second exposition. The increased pressure arises not from the draught of water, but from the bulk of water displaced, (we now allude to the ship at rest,) the addition of depth increases the weight of the ship faster than a proportionate increase of breadth; hence it follows, the ship displaces more water, by making her deeper, than by adding a proportionate breadth; and it will be at once perceived, that the deep, narrow ship, is working to a great disadvantage, carrying less, and of herself weighing more, or having more resistance and less propulsive power, or unable to bear an equal amount, which is the same in effect. We have shown, that steamers should draw less water than sailing vessels, not on account of the supposed increasing pressure, with an increase of depth, but because of the increased necessity of an upright position, the very reason why many builders advocate narrow steamers, the same reasons apply equally to sailing ships' breadth, adds stability in both cases. Another error demands a share of our attention while the subject of making models is under consideration. It is almost universally believed that the angle of resistance is at the surface of the fluid, or at the lines of flotation; how far, or to

what extent, this is the case, the reader may be able to judge by referring to Plate 2, the angle of resistance may there be seen to differ widely from that of the line of flotation, with the sheer and half-breadth plans; and we have set apart a portion of a subsequent chapter for an exposition of this subject; we shall not follow it farther than to point out the line thus delineating the angle of the resistance on the model from which it was taken. It will be seen in the sheer-plan, running from the stem above the load-line, extending aft and intersecting the sixth water-line at *l*, from thence to its lowest place at the centre of gravity, where it is found intersecting the second water-line; in its course aft it rises toward the surface, and again intersects the sixth water-line, between frames 27 and 28, and ends above the plank-sheer on the stern. It may again be traced in the half-breadth plan, as seen in the dotted line of the fore-body, or section 1 of Plate 2; this line, it will be observed, exhibits the angle of resistance on that model. It does not follow that it takes the same direction in the sheer-plan of all models, or of any two, (unless they are alike;) sufficient, it doubtless will be, for the present, to say, that it is the resultant of the right-angled pressure, which is not shown either by the water-line, the diagonal

line, or the section line. There is another subject connected with model making, that demands a share of our attention. Ship-builders usually make their models with a straight base-line, but lay the keel with a sag of several inches. To the practice of laying the keel with a sweep we do not object; so far from objecting we advocate a practice of still more, but we would have the model made just as the ship is required. The practice of making a model, and altering it on the floor of the mould loft, exhibits a lack somewhere, either that the builder does not know what he wants, or that his mind cannot grasp the ship as a unit. It is quite apparent, even to the casual observer, that no man can discover imperfections in form on the floor, as well as on the model; hence the importance of making the model just as we want the ship. The fore part, or the forward end of the keel, should be raised from a straight base-line, more than any other part; the reason of this is, that it must sustain more weight than any other part of the ship, in proportion to the buoyancy, and the keel is soon found to be lower forward than elsewhere, unless kept up when built. But this is not all; the ship is worked easier by having the base-line curved. Some persons have supposed, that the sweep need extend only to the bottom of the keel,

having the rabbet straight, or nearly so; this can be of but little advantage, as it leaves the flat of the floor very nearly straight, which is a great detriment to the speed of the vessel, while it is no advantage in any respect. If the model is a *fac simile* of the ship, we can work by the sirmarks for our sheer, and see at a glance exactly what we have. There need be no occasion for setting the sheer of a ship in the usual manner, with a rope; if she is like the model, and the necessary amount of care is taken in laying down, moulding, framing and regulating, the sheer may at once be set by the sirmarks. These remarks not only apply to the sheer, but to all parts of the vessel. We should know what we want before we begin to make the model, and having begun we should not stop short of satisfying ourselves; and we may rest assured, that if we cannot accomplish our purpose on the model, we cannot on the floor, or on the ship, however much we may desire so to do. When we begin

to make alterations from the first design, we cannot tell where they will stop; one change leads to another, and the alterations from the first plan keep pace with the progress of the vessel, and when finished, sometimes one finds that by endeavoring to please everybody, that he has pleased nobody, not even himself.

Those remarks apply to the internal arrangement, as well as to the shape of the ship, and if we progress with our work, to any considerable extent, before making all the arrangements, we begin before we are ready, and time and money may be saved by attending to this, no matter how short the time may be in which the vessel is to be built. The only way to drive work successfully on a ship is to begin at the model; one day spent there is worth a week on the ship, and although we do not always carry it out, yet we readily assent to the truth of the adage—that *Time is Money*.

CHAPTER IV.

Taking off Tables—Their Distribution on the Floor—Sheer Plan—Sheering in General—Its Intimate Connexion with the appearance of Vessels.

After having completed our model, the first consideration is to determine the distance between the moulding edges of the frames, giving the greatest transverse section, or $\otimes$ frame, a permanent location, or the starting point for future operations. Before this question can be settled, we must determine the siding size of the timber composing the frames of the ship, and the thickness of the chock that separates the faces of the timbers, having reference to the finish of the ship. If she is intended for passengers, with lights in the side, the chock should be smaller, in order that the light may come between the frames. The distribution of the timber should be as nearly equalized as possible, both for strength and durability, and having arranged the timbering room, we may mark every fourth frame from the $\otimes$, both forward and aft, until we approach the ends, when every other frame alternately should be also marked, and if deemed necessary, every frame may be marked near the ends of the model; circumstances must determine its necessity. This operation will extend the whole length of the model, and must be first made on the plane representing the middle-line or centre of the vessel. After having made these divisions correctly, measuring by the same scale upon which the model is made, we may square them across the water-lines, from the base-line to rail or upper sheer, these being the fourth frames midships, and are usually called the spawl-frames. It is now necessary to square them across the model to the outside on each successive sheer and water-line piece, and we may separate the model for this purpose; after which we can proceed to take off the dimensions for the floor, as in the following tables, the lower water-line being numbered one, and those above increasing as we ascend or approach the inscribed line of flotation at the surface of the water. The first parts of the tables required are those pertaining to the sheer plan, and exhibiting lengths and heights.

We may now see to the mould-loft.

TABLES OF PLATE 3.

Names of Frames	1st Height	2d Height	1 W. Line	2 W. Line	3 W. Line	4 W. Line	5 W. Line	6 W. Line	7 W. Line	1st Breadth	Rail or
	ft. in. shs	ft. in. shs	ft. in. shs	ft. in. shs	ft. in. shs	ft. in. shs	ft. in. shs	ft. in. shs	ft. in. shs	ft. in. shs	ft. in. shs
Stem	10 6 3	13 2 0	.....	.....	.....	.....	.....	.....	.....	.....	.....
F	10 6 0	14 7 6	.....	.....	.....	.....	.....	.....	.....	3 10 4	9 7 4
D	10 1 4	14 5 0	.....	.....	.....	.....	.....	.....	.....	9 3 0	13 7 5
B	9 8 0	14 1 4	.....	1 1 4	1 10 1	2 6 0	3 3 3	4 3 0	5 2 0	12 5 6	15 6 0
1	9 3 0	13 8 4	1 2 6	2 5 6	3 7 4	4 9 0	5 10 4	6 10 0	7 8 1	14 4 0	16 3 0
5	8 7 4	13 0 0	3 4 4	5 6 0	7 4 0	8 10 2	10 3 0	11 6 3	12 9 0	15 11 3	16 7 0
9	7 10 5	12 4 4	5 7 6	8 2 4	10 3 0	13 4 4	13 4 4	14 3 0	15 0 0	16 8 6	16 8 7
13	7 4 2	11 9 0	7 9 0	10 9 0	13 7 4	14 10 0	14 1 6	15 7 6	16 3 5	16 10 2	16 9 6
17	6 10 0	11 3 5	9 6 2	12 6 0	14 2 0	15 3 6	15 10 2	16 6 2	16 10 6	16 10 6	16 8 6
21	6 6 4	10 10 0	10 10 6	13 7 0	15 0 7	16 0 0	16 11 0	16 8 5	17 3 2	16 6 2	16 7 7
25	6 2 6	10 6 3	11 10 2	14 2 6	15 5 1	16 5 0	16 11 2	16 10 0	17 3 5	16 7 2	16 7 2
29	5 11 7	10 1 1	12 2 2	14 4 2	15 8 0	16 6 6	16 11 4	16 11 4	17 3 6	16 8 0	16 6 6
33	5 11 5	10 3 0	13 0 0	14 4 3	15 8 4	16 7 0	16 11 6	17 0 0	17 4 0	16 8 4	16 6 2
37	5 11 6	10 1 6	11 3 6	13 9 0	15 4 5	16 3 6	16 9 0	16 9 6	17 7 1	16 8 2	16 4 2
41	6 0 0	10 3 0	9 9 0	13 11 2	14 8 2	15 9 0	16 3 4	16 7 0	16 11 4	16 8 0	16 2 0
45	6 0 7	10 3 0	8 3 4	11 7 7	13 9 0	15 0 0	16 4 0	16 10 0	16 10 6	16 7 6	15 11 7
49	6 1 2	10 4 1	6 7 5	10 1 2	13 6 0	14 0 0	15 0 5	15 9 0	16 4 2	16 7 2	15 9 6
53	6 2 5	10 5 6	5 2 6	8 4 3	11 0 0	12 7 6	14 0 0	15 1 5	15 9 0	16 5 0	15 8 0
57	6 5 4	10 8 0	3 7 6	6 7 4	8 11 6	11 0 0	12 7 0	13 10 7	15 0 3	16 3 0	15 6 0
61	6 9 0	10 4 4	2 4 1	4 9 0	6 8 0	8 5 7	10 4 2	12 4 0	13 8 2	15 8 6	15 3 0
65	7 1 0	11 2 6	1 2 0	3 4 4	3 2 6	5 4 0	6 8 0	8 6 5	10 4 4	15 4 0	14 10 6
69	7 5 2	11 6 0	6 4	9 0	10 4	1 3 0	1 9 0	2 2 7	3 2 3	13 9 6	14 6 6
Cross seam on .....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	12 3 0
Rail on stern .....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	14 0 0
Rake of stem from .....	.....	.....	5 0 6	7 10 0	9 0 0	9 10 0	10 7 4	11 4 2	12 0 0	15 9 5	19 6 0
Rake of post from .....	.....	.....	.....	.....	.....	.....	.....	.....	1 7 4	7 0 0	9 7 4
69 on base 7 inches	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....

REMARKS.—Rise of Stem on Frame 1, 4 inches; Water Lines 2 feet apart.

TABLES OF PLATE 5.

Names of Frames	1st Height	2d Height	3d Height	4th Height	5th Height	6th Height	7th Height	8th Height	9th Height	1st Breadth	2d Breadth	3d Breadth	Rake of Stern from Frame Q.
	ft. in. shs	ft. in. shs	ft. in. shs	ft. in. shs	ft. in. shs	ft. in. shs	ft. in. shs	ft. in. shs	ft. in. shs	ft. in. shs	ft. in. shs	ft. in. shs	
Stem	5 10 3	9 3 5	11 1 2	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Frame S	5 7 2	8 11 6	10 9 3	0 10 0	1 6 5	2 4 5	3 0 7	4 11 5	5 5 2	6 11 0	7 0 7	8 5 3	1st Water Line 2 3 6
Q	5 1 6	8 7 0	10 4 5	0 10 0	1 6 5	2 4 5	3 0 7	4 11 5	5 5 2	6 11 0	7 0 7	8 5 3	2d do. do. 3 10 0
O	4 9 1	8 2 4	10 0 4	1 11 0	3 6 0	4 10 0	5 0 5	6 2 6	7 3 7	8 10 6	9 1 1	10 6 1	3d do. do. 4 6 7
M	4 4 0	7 11 0	9 8 3	3 1 6	5 4 4	7 0 5	8 5 0	10 6 3	11 5 2	12 9 3	13 3 6	14 5 4	4th do. do. 5 1 6
H	3 8 6	7 4 4	9 4 0	6 9 4	8 8 5	10 3 4	11 3 4	12 4 2	13 7 3	14 6 7	15 13	16 5	5th do. do. 5 7 6
D	3 3 6	6 11 0	8 9 0	8 1 0	10 8 7	11 11 4	12 6 4	13 9 4	14 13 10	15 3 12	16 8 0	17 19	6th do. do. 6 1 2
Q	3 0 0	6 8 4	8 5 3	8 11 0	11 5 3	12 5 5	13 10 4	14 0 0	15 0 0	16 11 0	17 10	18 12	1st Breadth 7 6 4
4	2 10 5	6 6 6	8 4 1	8 3 0	11 1 6	12 2 6	13 8 4	14 12 10	15 10 12	16 8 6	17 5 12	18 5 4	2d do. 8 11 4
8	2 11 0	6 7 3	8 4 4	7 2 4	10 2 0	11 7 0	12 3 4	13 7 4	14 8 3	15 7 4	16 5 1	17 4 0	3d do. 10 5 0
12	3 1 3	6 8 5	8 5 6	5 6 4	7 5 10	8 5 3	11 3 6	12 3 2	13 6 0	14 5 5	15 3 5	16 12	Rake of Post
16	3 3 3	6 11 0	8 7 3	3 6 6	5 4 8	8 0 10	3 6 11	5 5 13	6 13 3	7 3 0	8 4 11	9 11 3	from Frame 26 0 0
20	3 7 4	7 3 0	8 11 0	1 10 7	3 9 7	5 10 2	7 10 5	9 10 0	11 1 2	12 11 4	13 9 6	14 7 5	At Base Line 2 5 0
24	3 9 5	7 5 0	9 1 4	1 4 3	3 8 5	5 3 0	6 1 2	8 2 5	10 2 2	11 9 3	12 8 5	13 5 5	6th Water Line 3 1 0
28	4 0 0	7 6 7	9 3 4	0 10 3	1 8 1	2 7 4	3 11 0	5 9 0	8 1 7	11 5 7	12 6 11	13 3 2	1st Breadth .. 4 3 4
32	4 1 6	7 9 0	9 5 2	0 6 0	0 9 3	1 1 7	1 7 7	2 4 5	3 8 4	10 9 2	11 4 6	12 1 0	2d do. 7 11 4
36	4 3 0	7 10 0	6 6 2	0 3 5	0 4 2	0 5 2	0 6 6	0 8 5	1 0 5	2 5 4	3 1 10	4 11 2	3d do. 9 0 3
Stern	4 4 0	8 1 3	9 9 4	.....	.....	.....	.....	.....	.....	.....	11 0 6	10 8 2	.....

REMARKS.—1st Water Line 18 inches above base, those above 2 feet apart. Frames 2 feet 6 inches apart. Stern Post straight 19 ft. 6 in. above Base Line. Knuckle of counter on centre of stern, 17 ft. 6 in. above Base Line, and 6 feet 4 inches and 6 ft. 4 in. aft of frame 26. Round of stern at counter 15 inches, 1/4 width at knuckle 10 feet 3 inches square from middle line both ways, vertical and longitudinal. Round of stern, at 3d Breadth, 15 inches, and at Rail 16 inches.

If we have not floor-surface sufficient to lay the ship down her whole length, which is rarely the case, (however desirable to those who are unaccustomed to the operations of the loft,) but have length enough to accomplish our purpose by dividing her into two sections, we should be satisfied, as it is quite enough length. First, strike a base-line on one side of the floor, the length of the loft, and above this line the water-lines may be set off. Having proceeded thus far, we will next inquire how much length is required from the ⊗ frame to the front of the cutwater, as the mould-loft is the place to lay down the head, as well as the ship itself. We should have length enough to extend four frames at least into the after-body, but eight would be preferable. When sufficient lap cannot be obtained, we may allow no room for the head, but let the stem take a position at the end of the loft; the fourth frames may be set off on base-line and squared up. If the ⊗ frame is about the centre of the ship, and we have a sufficiency of length for the head, and from thence to the ⊗ frame, we will have the length, or the distance the head projects for lap, which may extend to five or six frames, and will in such cases be found sufficient.

We will assume, in the case before us, that the loft is long enough for such

arrangement, and proceed with the work. We now have the several water-lines and the fourth frames in the fore and after-body, as marked on the model.

The frames may now be marked, as in Plate 3, or as is the usual custom, which is to number the after-body, and naming those of the fore-body in alphabetical order. When this course is adopted, we should have the arrangement as follows: ⊗ D, H, M, Q, &c. It is sometimes thought best to leave J out of the alphabet, when K follows. This arrangement avoids the liability to transpose I for J, when framing.

It will be remembered that the line we have denominated the base-line, is also the middle-line, or the centre of the vessel, and that it is the base-line for both bodies of the ship, the fore and the after-body; but it is quite evident, that to have the alphabet marked as the example just shown, in the usual place, which is below the base, would shut out the numbers of the after-body, or if they were also marked there, it must be quite apparent that there would be liability to mistakes. In order to avoid this, we may number or letter the fore-body, above the sheer lines. For example, suppose that we have every fourth frame lined on the floor, and that our loft is but long enough for a lap of four frames, we begin the after-

body at D or 29, from which to ⊗ will be the lap. We then have ⊕ 4, 8, 12, 16, 20, 24, &c., up to 36; or, as in Plate 3, ⊗ 37, 41, 45, 49, 53, 57, 61, 65, 69. In the fore-body we have ⊗ where 40, or where 73, (in Plate 3, Section 2,) would be in the after-body, which makes provision for the lap of 4 frames; as D, or 29, are found in both bodies: the stern would project nearly, or quite the distance beyond 36 that the fourth frames are apart. It then follows, if 40 and ⊗ would be the same frame, assuming Plate 3 to have been lettered forward, instead of numbered, 36 and D would also be the same frame; 32 and H would also be the same frame. This arrangement is precisely the same as in Plate 3, with this exception, that in the latter the numbers begin forward, at the foremost square-frame, and continue aft; the few frames forward may be marked in alphabetical order. This arrangement, or that shown in Plate 2, or the present course, as already described, may be adopted, with equal success; it makes no difference which, provided we continue in force throughout the method we first adopt. When the vessel is long, and there are more frames in the fore-body than letters in the alphabet, we recommend the method adopted on the ocean steamer, of taking up the small Italic alphabet, as in Section 1 of Plate 2, or as shown in

the tables of Plate 5, after having exhausted the Roman alphabet. We have assumed, in the arrangement now commenced on the floor, that the two bodies on load-line are of equal length, or nearly so, as in Plate 3—hence, it will be quite apparent, that if we have room to append the head, that the fore-body requires more length of loft than the after-body, and to balance the bodies, we have given all the lap to the after-body.

We have been thus particular in describing arrangements, lest the reader, who may not be familiar with the operations of the loft, should get confused, and lose the force of our expositions. There is no difficulty in laying down the vessel entire, even though it may require three lengths, as in Plate 2, before making moulds, and at the same time have free and ready access to every part of the operation, provided the arrangements are clear and comprehensive in our minds. When our floor is too short to lay the vessel down in two lengths, we have only to so arrange the three sections, that each fourth frame will represent three frames, one of each section, and numbering the after-section at the base-line, the middle section at load-line, and the forward section above the rail, or at the side of the loft. It has been quite common, where floor-room has been insuffi-

cient for the operation in one or two lengths, to lay down one section of the vessel, and make the moulds, before laying off the second. This may be necessary where we are in great haste, but it is seldom attended with any real advantage. True, we get some moulds a few days sooner, but our supply is suddenly cut off, and we are waiting for a second; whereas, had we continued the operation of laying-off, at the time the moulds came from the second section, we should have received them from the first, and they would have been continuous. But this is not all; vessels are found to be more difficult to regulate, and are not as fair when thus laid down, for the following reasons: First, should there be any discrepancy in one of the lines, we do not know which frame to charge with the fault, unless we have another section at hand. Supposing that after the first section is laid down, and the moulds made, we discover in sweeping in the frames of the second section, that one or more lines must be altered to make the frame fair; but we cannot alter without extending the same beyond the lap into the first section; hence we see, that it is in this manner we often take what we do not want, or would not have, if we could go over the work again; but this cannot be done, as the timber is perhaps all worked, and thus men are

driven in their haste to give their assent to what they know to be wrong. These discrepancies, to a man of taste, are like a night-mare, brooding over his mind, and mirroring and expanding them before him.

Where the model is made by the eye, and dependent upon the same on the floor of the loft, the vessel should be all laid down, or at least the lines should be proven in their whole length, before any moulds are made. That vessels can be laid down on a floor the size of the body plan, does not admit of a doubt, but it requires more time, and is more liable to error; but when we leave the eye, and make an exchange for a system of proportions that can be carried out by calculations, we are less dependent upon the second section for proof of the first, or upon the third for proof of the second.

If our floor should not be sufficiently wide to lay down the vessel in her whole depth, we may divide the depth into two sections; the boundary lines of the lower section should in such case be the base and load-line, and of the upper section the base may be regarded as the load-line, and the sheer-lines above. Having our arrangements made to the best advantage for elucidating the operations on the floor, we shall now proceed to take off the heights, as obtained from the model, on

every fourth frame above the load-line, and to set off the stem and stern-post as measured on the water and sheer-lines, from a particular frame designated for the purpose, as in the tables of Plates 3 and 4. Those lines at opposite ends of the loft, form the longitudinal boundary-line of the ship—the line representing the stem is the inside, or aft side of the same, and whether we adopt the proposed improvement or not, of having the stem inside the ship, it does not alter the lines on the floor. This line extends from the rail to its intersection with the base-line, which should have some rise at or near its intersection with the stem; hence it is quite clear, that the margin-line, or line showing the inside of the stem, is but a continuation of the base-line, although bearing another name, beyond a certain point.

This also applies to the stern-post, as high as the cross-seam, so that in truth the base-line extends from the rail to the cross-seam.

We are thus particular in defining this boundary-line, on account of the ending of lines, a part of the operation that is usually so perplexing to beginners. From the cross-seam we may now extend the counter archboard and stern, remembering that the part of the stern shown in this line is at the centre, and consequently the longest part, or that farthest aft.

We now have the sheer-plan of both bodies, that of the after-body extending from the stern at the centre, to frame 29, or frame D, showing the heights of all the frames between those points, at the several sheers, and all the water-lines running parallel to the base, at their respective heights, and terminating successively above each other, on the inside of the stern-post.

The same remark, made of the stem, as to its being inside or outside of the ship, as they now are, applies to the stern-post also. As the sheer plan shows lengths and heights only, the after-body, by previous arrangement, is numbered below the base-line. The fore-body is likewise represented in the same base-line, water-lines, and frames, the water-lines being parallel to the base, and the distance between the frames being equally spaced. We have the same frames in the fore-body that are shown in the after-body, and may be numbered or lettered, as before stated, on the floor above the sheer-lines.

Having given the boundary-line of the sheer plan, a word of instruction may not be out of place in relation to sweeping in the sheer of the two bodies. We should remember, that the round edge of the batten is the best to look at in fairing the sheer, or other lines on the floor, and they should lay on their flat, the edge to the spots. We may place

the battens to one or all the sheers, at the same time; if, however, the sheers taper, one at a time is quite sufficient; when they are parallel, they may all be regulated at the same time to advantage. The sheer of the after-body should be swept first in this instance, because the lap is appended to this plan, and after regulating the sheers of this body, and marking them on the floor, we may take the heights at $\otimes$ and 29, as in Plate 3, Section 2, or on $\otimes$ and D, according as the arrangement is made in numbering or lettering the fore-body. Those heights are to remain unaltered when regulating the sheer of the fore-body, and although the sheer of the two bodies will be found to cross each other, and are thus kept apart, there will be no cause for difficulty in tracing them. We may next set off the thickness of the plank below the baseline, at the termination of the straight rabbet on the keel forward; square from the same, and continue to do so, at intervals, on the stem, its entire length to the head, measured square from the line representing the inside of the stem. This operation will be required on the stern-post likewise, and measured square from the inside of the post.

It will be discovered that were the rabbet-line extended along the keel, that we should have two continuous lines

from the cross-seam, or the margin-line, as it is called by many, to the head of the stem, or to the lower side of the plank sheer, known as first height in Plate 3, and the space between these lines is to be filled with the end of the plank, on the stem and post, and with the edges of plank on the keel.

The forward-line on the stem, the lower-line on the keel, and the after-line on the post, represent the wood ends on the post and stem, and the garboard seam on the keel; but the direction from this seam inward, or aft from the stem, forward from the post, and upward from the keel, remains yet to be defined. It is important that this part of the work should be clearly described and understood, inasmuch as it has been considered a complex problem, in practical operations, mostly on account of the constant change that takes place in the bevel of the rabbet. We may draw the sweeps for the ends of the water and sheer-lines, before or after setting off the half breadths on their respective frames. We will, in the case before us, proceed to end the lines in the half-breadth plan, commencing with those on the stem. In order to render the ending of water-lines clear and comprehensive, we shall divest the matter entirely of every vestige of the hereditary notions that have hung around this subject for so many

years. We have shown that the line showing the end of the model on the bow and post, in its continuation, also represented the base-line, or top of the keel.

It will be necessary to set off above the base-line, in the sheer plan, which is also the middle-line in the half-breadth plan, half the size of the stem and stern-post; those lines need extend no further than the rake of the stem and stern-post requires, and will represent the siding size of those important parts of the ship. Should the stem be larger at the head than the size of the keel, which is highly necessary, half of that difference will be shown in the opening between this line, which is called the side-line, and the middle-line. The same remark is equally applicable to the stern-post, and its size, when determined, can be shown in the same manner by the space between the middle-line and this side-line. This method is applicable to the present mode of adjusting the stem and post outside of the ship, with the exception of the thickness of the plank, which always extends beyond this boundary-line, forward on the stem, downward on the keel, and aft on the stern-post. This simple problem has been rendered abstruse, in consequence of writers having confounded the final termination of lines with their intersec-

tion with the side-line, or the termination for the inside of the plank with that of the outside.

This is wholly unnecessary; all the knowledge the pupil requires in the loft upon this subject, is enough to enable him to mark the spot where the water or sheer-lines, in their rotundity, cross the side-line on the inside of the plank. It is plain that the outside corner of the stem on the model, is the inside of the plank, and this represents the inner corner of the rabbet. It is also plain that we cannot have the wood ends on the outside of the plank of the same sweep or shape as the inside of the stem, if we adhere to this inside or corner line for the ending of all the lines, unless we cut an unfair rabbet, and subject the butts in some parts to a strain in caulking that would be likely to start them. But this is not all:—the shape would be of less consequence than the danger to be apprehended from the oakum following the seam that divides the stem from the apron, and instead of caulking the butts of the plank, the stem and the apron would be subjected to an unnecessary strain, while the butt would remain uncaulked.

To obviate this, and still bring the lines to their proper place, it is only necessary to square this corner or margin-line, out to the side-line, which is done by squaring down the water

and sheer-lines from their intersection with the line showing the inside of the stem and stern-post to the side-line; those spots being marked, we may take a pair of compasses and set them to the thickness of the plank at the rabbet, (which should be less than on the other parts of the ship, as we shall show.) We may now apply one leg of the compasses to this spot, and the other in the side-line forward, turning on the last leg and sweeping inward, thus marking on the floor a quarter circle in the direction of the line, as shown in Plate 4. Some persons may suppose, that because the rabbet is swept on the stem, that this outside line should be squared down; but this error will appear quite manifest, if the individual who is thus revolving the subject in his mind, will take a model in his hand and examine the subject, after reading our remarks upon this particular part of the operation.

In those expositions we have assumed the dead wood to be of the same thickness as that of the stem, and the bearding-line will vary proportionately as the dead wood is thicker or thinner than the keel. The importance will at once appear of making the stem, stern-post and dead woods, the same as laid off on the floor in thickness. There is an apparent discrepancy in thus ending lines, con-

sequent upon the rake of the stem. It is evident that the water-lines in the sheer-plan, if extended to the forward edge of the rabbet, would show an increasing length on each line, as we descend toward the keel, while the rabbet remained the same size, the whole length of the stem, when measured square from the margin, and in consequence of the increasing rake of the stem as we descend, a rabbet that is only three inches on the square, may be found to measure a foot on the water-line.

Now, it will appear quite manifest, that if the outer edge of the rabbet were squared down to the side-line, and the thickness of the plank swept in square, either from this point or from the size of the rabbet aft of this point, the ending would not compare with the half-breadths, as taken off the frames, and as a consequence, would be unlike the model. Thus we discover that the margin of the stem is the fixed point for the intersection of the sweep with the side-line, the centre of which sweep is as far forward as the size of the rabbet, when measured square on the stem; the circle once obtained, we have the ending of the line, as it matters not how sharp or how full the vessel may be, the line intersects the circumference of this circle, and thus provision is made for the plank, which will be in-

variable, while our compasses, or the sweep they make, remains unaltered. The bearding-line is a second rabbet-line formed by the lines showing the inside of the plank, in their intersection with the side-line.

It will be remembered, that in our expositions of the manner of ending lines, the line swept in, forward of the margin-line, for the inside of the stem, is the boundary-line for the outside of the plank, consequently the groove, or rabbet, commences here and cuts inward, square from the line in its rotundity, until it reaches the required depth of the rabbet, when it takes the course of the line and emerges at the side-line on the inside of the plank, as shown in Plate 4. This line is necessary to determine the moulding size of the dead wood, both forward and aft, in the sheer-plan, as the cants terminate their moulding and bevelling edges at this line—hence, it must follow, that to render the heels of the cants secure, the dead wood must reach a sufficient size, or depth, to cover their heels that come against the dead wood.

Those remarks apply equally well to both ends of the ship, and this part of the operation will be required before the ship is all laid off on the floor, although many defer this part of the work until a later period, and the consequence is, that the ends of the ship

do not keep pace with the middle, or more bulky parts. It is necessary to forward the bow and stern of the vessel as fast as possible, in order to keep them in the same state of advancement with other parts of the ship, for the following reasons:—there is a great amount of work to be done within a small compass, and as a consequence, but few hands can work to advantage; hence, the necessity of obtaining the required shape, dimensions, and moulds pertaining to those parts, as early as practicable.

Many builders in Europe, and some in the United States, make a dead wood mould for both ends of the ship. This is altogether unnecessary—the stem mould being all that is required—the size of which is of no farther consequence than to be of sufficient size to embrace the rabbet, bearding and base-lines.

Naval Architects have confused the minds of their readers, by making many more lines than is absolutely necessary, in laying off on the floor, while maritime enterprise leads to the shortest, or most direct course, to arrive at the same end. European works upon this subject, even those of latest dates, confound this whole subject with a description of an inner and an outer rabbet, evidently following the directions laid down in the musty folios of the past.

The mechanic who would undertake to follow those directions, with no other instructions than there found, will find himself perplexed and confused, but not instructed. What we have already said in substance, we now repeat in so many words: we need recognize but two lines on the floor as immediately connected with the rabbet—the first is the inside of the stem or post, and baseline, which we have for distinction called the margin; the second is the bearding-line, which is the forward part of the rabbet on the dead wood aft, and the after part of the rabbet, on the dead wood forward; the outside of the plank need not be shown on the floor.

When we determine to put the stem and the stern-post inside of the ship, for reasons given on page 102, and illustrated in Fig. 14, we need not end the lines, or form the rabbet, until after we have distributed the tables or half-breadths, on their respective frames in the half-breadth plan; we may set off both bodies before sweeping either, remembering to sweep in that body first, which has the lap appended to it. When we adopt the internal stern-post, we may square down the margin-line from the sheer to the half-breadth plan, at the several water and sheer-lines. We may obtain a setting-off on those spots, thus squared down, by taking half the thickness at

those terminations, from the model, or draught, as shown in Plate 3, Sections 1 and 2. Having distributed the half-breadths of the water-lines, we may proceed to place the battens to the spots on the several frames. It is desirable to regulate all the water-lines at the same time, or to have all the battens required for this purpose on the floor at the same time, as one line determines, to some extent, the correctness of the other. The variations, however, will be inconsiderable, if proper care is taken in preparing the tables from the model; the battens will come together at their ending, but they may lay one above the other until regulated.

Some builders, while regulating the half-breadth plan, select a convenient part of the floor, and lay off the transverse sections of the ship at the same time. Those sections exhibit another view of the vessel, and fall within each other, showing the shape of every square frame at its moulding-edge, or at the inside of the plank; it is usually called the body-plan, like that of Section 4 of Plate 2, or that of Plate 5, from the tables of the same. The half-breadth one way, and the entire depth of the ship the other, is necessary to lay down the fore or after-body. This plan is bounded by a middle-line, which represents the centre of the stern-post

for the after-body, and requires a base and water-lines the same as the sheer-plan, and it is important that the water-lines should be spaced the same as in the sheer-plan, else we may find discrepancies which we would hardly be willing to accredit here; and in all our measurements on the floor, we should remember that there is no room for the common expression, *that is near enough*.

There is a large surplus about every ship-yard, without carrying it from the mould-loft with the moulds and bevelings; the winding of the timber, supposed to be sided fair, the large quantity that is not sided, and the bad bevelling of the frame, in addition to contingent circumstances, growing out of ignorance and carelessness, will afford the careful man abundant reason, when the ship is raised, to say, that with all his care, she is not as near the mark as he expected she would be.

When this method is adopted, the same tables may be worked from for this plan, that have been used for the half-breadth plan. The line showing half the size of the keel and post, in the half-breadth, must be set off from the middle-line, the same in both plans; at the base-line the space must be half of the size of the keel, and at the cross-seam, half that of the post at that height, as in Plate 5.

The heights of the sheer-line must be taken from the floor, measuring from the load-line to each height on its respective frame in the after-body; they should be taken on a small batten, and transferred to both sides of the after-body plan. This being done, lines may be stricken across the half-body plan, representing the height of every fourth frame, and numbered to correspond with the sheer-plan. If we have battens enough, (and we never lose by having a good supply,) we may run in the sheer-lines in the half-breadth, and then we are prepared to sweep the fourth-frames in the body-plan. The battens may now be placed by the spots, as taken from the tables, making the variations to correspond with those of the half-breadth. The heights in the sheer-plan are called breadths in the half-breadth and body-plans.

We now have the whole after-body of the ship spread out before us in three separate plans, and it may readily be perceived that the one should correspond with the other, and as we have the spots taken from the same tables in both bodies, or plans, whatever variation we make in one body must be made in the other. Thus the longitudinal planes are expanded to the full size of the ship, as seen by the water-lines, (as they are commonly called,)

or the battens showing those lines, and the shape of the frames are also shown, as in Plate 5. It must be remembered not only that the breadths at every water-line and sheer-line must agree in both plans, but that the lines must be fair, as well as the frames; should there be a wide departure from a spot made or measured from the tables, we should go back to the model, and ferret out the discrepancy. If our model is fair, and we are as particular as we should be, the variation from the spots would not exceed one quarter of an inch on any part of the tables thus taken from the model.

The ending of the frames in the body-plan is precisely the same as that of the half-breadth; the compasses are set to the thickness of the plank, and one leg placed in the corner where the base and side-lines cross each other. The second leg is placed on the side-line below, and a quarter circle swept from the base-line inward, the compasses turning on the lower leg below the base-line. It will be remembered that the rabbet swept on the stem and stern-post was somewhat less than the actual thickness of the plank; but we are now on the bottom of the ship, or on the side of the keel: the rabbet here may be swept to the full thickness of the plank, and extend the whole length of the straight rabbet for-

ward, and within a few feet of the post aft. It is assumed that the keel is of parallel thickness, consequently but one sweep is necessary for the ending all the square frames in the after-body.

We now have spots for the battens in the body-plan, on all the lines from the rail to the rabbet, on the keel, and the battens must end on the sweep made for the rabbet; and if we are particular we will discover that as we go aft the frames rise with regularity on the side-line above the base, and those risings furnish the settings off for the continuation of the bearding-line below the first water-line, both forward and aft, and will be found to agree as far as the frames may extend.

Our remarks in relation to the extent of the square-frames do not affect our present arrangements in the ending of the frames to prove the lines; and although we have designated the space allotted for the cants in Plate 3, Sections 1 and 2, yet we have continued the square-frames, as shown by the dotted lines, to the extremities of the ship; consequently, those frames, although not intended to delineate the shape of moulds, are taken off the model, and set off on the floor in the same manner in which other square frames are; they end on the sweep also, in like manner, and their intersection with the side-line furnishes the

distance from that point to the base-line, which is also the distance on the same frame from the base to the bearding-line. By thus ending the frames on the sweep, we retain an equalized rabbet, and a straight garboard seam, if we choose to adopt it. Where the keel tapers in thickness, which is sometimes the case in smaller vessels, we require a new side-line for every frame coming over the tapered part, as it is plain that the side-line showing the side of the keel, or the sides of the stem and stern-posts respectively, must be directly over, or at the part it represents. This remark applies also to a rise of the stem and keel; the $\otimes$ frame being the lowest, it follows that the base-line and rabbet-sweeps must rise as we advance either forward or aft. We shall give a fuller exposition of this part of the operation when we shall have advanced as far as the cants, with which, at present, we have nothing to do.

We will now renew the work:—the battens, we will assume, are tacked to the frames in the body-plan, and to the water and sheer-lines in the half-breadth-plan; the heights have been swept in the sheer-plan, and if the horizontal lines in the body-plan have been taken correctly, and the breadths, as shown by the battens in the half-breadth plan, correspond with those of

the body-plan, and are both fair, they are correct, and may be marked with a thin piece of white chalk, in the half-breadth plan; and we may here remark, that some care is requisite in marking the lines as well as correcting them. As soon as the lines are marked the battens should be released from their curved position, on account of their tendency to retain part of the curve or lose their elasticity; and while upon this subject we will add, that the battens should never remain from one day until the next tacked to any considerable curve or line, if we expect to use them for a similar purpose a second time.

We may now proceed in the same manner with the water-lines, marking them within a few feet of their ends, and after removing the battens, taking a shorter batten and carrying out each line to its proper termination, or to the sweep belonging to said line; and in accordance with our determination in relation to the parallel or tapered stern-post, siding ways, the frames may also be marked in the body-plan temporarily. We may now determine the size required for the stern-post, assuming it to be placed inside of the ship—we have the ending of the water-lines, and along for several feet forward of those endings, we may place a batten to the thickness of the plank from the line,

and parallel to the same, marking the line, and proceeding to the next, and continue until all the water-lines are thus circumscribed by an outside line, the space between equalling the thickness of the plank, or the depth the rabbet on the post is designed to be.

* Having extended this operation as high as the load-line of flotation, we may now inquire the size of the post on the after-edge. If we follow the leadings of the keel, we would have it the same size as the keel, but as it is the usual custom to taper the after-end of the keel, we may follow the practice of the age, when nothing will be lost by so doing.

We shall now find it necessary to assume such dimensions for the aft edge of the post as correspond with those before us, and with the dictates of our judgment, half of which may be set off and lined aft of the margin-line of the post. This opening, or space, shows half of the stern-post on the after side, and the lines may be brought to agree, if there should be variations between the load-line and the base-line, as the size of the post is mainly determined by the ending of the same.

The amount we may deem it necessary to reduce the post below the size of the keel, at the base-line, will also determine the increased size of the post above that of the keel, an equal dis-

tance above load-line, with that of the base below the load-line—hence, we shall at once discover, that to make the post on the aft edge, about the same size as the siding size of the keel, will be a near approximation to the proportionate dimensions.

The cross-seam being nearer the load-line than the base, or the space being shorter between the load-line and cross-seam, than between the load-line and base-line, it follows that the post would not be as much larger at the cross-seam, than at load-line, as it was smaller than load-line at the base.

It will be quite manifest, that the moulding side of the post outside of the rabbet, will be determined by the thickness of the post on the after-edge; and in order to harmonize those parts, we should first determine how much face of post we require between the wood-ends and the aft edge; and next, how much the post will side by measuring the piece of which it is to be made, the largest part of which is about the load-line, and at the edge of the rabbet. If we find the post is not large enough to work by those dimensions, we may line the rabbet farther aft, and the edge of the post also farther aft. This, of course, reduces the size of the post above water, and at its surface, and as a consequence, the siding size of the rudder; but we must remember that

we require but little more than half (and in some cases not half) the rudder that we require under the present practice.

It is not important that the bearding of the post should continue to follow the angle of the lines above the load-line of flotation; it may gradually fall into the parallel siding above, or be carried up by the same angle as that at load-line. We should bear in mind, that as we require much less exposed siding surface to the post at the head, than at the heel, the strain arising from the caulking being in another direction, and not wholly dependent upon the same means for support, (the fastening through the post aiding materially,) we need take no more than is necessary; by carrying the edge of the rabbet aft, at the head and forward, at the heel a smaller piece of timber will make the post.

Having arranged the ending of the lines for the post, we may now carry any alterations that may have been made in consequence of the change, to the body-plan, and if the alterations continue to make a fair frame with a new ending for the keel, if required, we may regard the half-breadth and body plans of the after-body as having passed through the first proof test of their correctness, and we may now regulate the bearding-line in the sheer-

plan, making it to correspond with the alterations in the half-breadth; to do this, it will be necessary to determine the size of post forward of the rabbet. These dimensions are not arbitrary; that is to say—the post need not of necessity come to any definite distance from the rabbet, or to any positive angle of rake; if the post will work large, make it what it will work—the more of post we have, the less of other timber will be required as dead wood to cover the heels of the cants, and the additional size also renders the post still more secure. That part of the stern-post inside of the rabbet may be sided to the size of the keel, in which case there would be no alteration required from the former arrangement in defining the bearding-line, as the dead wood would be sided to the same size; but should we taper the inner part of the post, by making it larger at the head than at the heel, the dead wood would require to be of the same dimensions, not only at the joint where the post and dead wood meet, but the same sizes must be continued parallel to the base-line; that is to say—what the size of the fore-side of the post is, four feet above the base-line, that must be the size of the after dead wood, its whole length four feet above base, and so of any other height.

When the post and dead wood taper,

the half thickness must be taken at every water-line in the following manner: first, by striking diminishing-lines the length of the post, the space between them being half its siding size on the forward edge. This may be shown on the aft side of the post; the line showing the half size of the aft edge will also form one of the lines, and the other will come abaft the first; the water lines crossing those lines at their proper heights, will show the half thickness at those points, which must be set off from the middle-line, and lined parallel to the middle-line for a side-line. Where those new side-lines cross their respective water-lines in the half-breadth, there is found the spot for the bearding-line in the sheer-plan; and those spots or crossings may be squared up to their respective water-lines, when the bearding-line may be swept in by those spots. But another alteration is consequent upon a tapered dead wood: at the ending of the frames on the dead wood their heels rise successively above each other; hence it is plain that the farther aft the frame the higher it ends, and the higher the frame ends on the dead wood, the thicker the dead wood is found to be, and consequently this extra thickness must be taken off the frame. But this apparent difficulty is at once reconciled, by showing the half size of the inside of the post in the body-

plan in addition to, or without the outside size of the post in the body-plan, as in Plate 5. This side-line, it will be seen, is not parallel to the middle-line, but shows the size of the post at different heights; hence it is plain, that no matter where a frame may terminate or intersect the side-line, it at once shows not only a correct ending for the frame, but the correct side-line for the heels of the square frames or cants, as the case may be. We next come to the ending of the sheer-lines of the after-body; we have already shown that the line representing the stern in the sheer-plan, is at the centre; hence it is plain that the lines do not end there. Few ship-builders have direct reference to the model when building the stern of a ship, or that part of the stern above the main transom; they may make the centre of the stern to correspond with the model, and this is about all; they in general have moulds of a few of the prominent parts of the stern, and make all shaped ships in other respects tend to this shape, or to these moulds.

The same remarks will apply to the head, and this is doubtless the principal reason why so small a portion of the stern finds a place among the illustrations on the floor. We cannot discover any reasons why the model of a ship will not delineate at least the shape of the stern, as well as the rake of the same,

at the centre only. If we will take the trouble to shape the stern on the model to please our fancy, or if we prefer the beaten track of our neighbor, we may show either, upon the floor, with the same degree of exactness that characterizes any other part of the ship. First, divide the stern of the model, or the after-body-plan, into nearly equal parts from the middle-line, and strike lines from the $\otimes$ frame in the body-plan to the rail of the same, parallel to the middle-line, as in Plate 5; these lines are called section-lines, and are usually extended no higher than the cross-seam; we may now set a gauge to the size by the scale represented on the floor, from the middle-line to the first of these lines called the first section-line; run this gauge-mark on the stern of the model, and the second and third sections in like manner; these gauge-marks need not extend below the cross-seam on the model; any other marks will answer as well as those, and the reasons for recommending them were that they were more easily made, and more likely to be correct than the course commonly pursued, particularly if the stern has any considerable round and twist. Assuming the model to be separated, we may now take the distance within a square, of the first, second and third section-lines, on the upper sheer-piece; this may be done by applying the stock of a square to the middle-line, and the tongue across the model, the edge of which is held to the section-line, and the distance measured from the edge of the square to the centre of the stern on the middle-line, by the same scale upon which the model is made; these distances must be set off in the sheer-plan, and on the same sheer-line on which they were taken, and in the following manner: apply the rule on the sheer-line, and mark successively the distances from the centre of the stern to each section-line forward of the centre; the outside corner must be also taken in the same manner. The process of taking off those stern-sections is alike on every sheer-line, as also that of the corner, as represented in Plate 3, Section 2—it must be remembered that this only applies to what is called a square-stern vessel. Thus we discover, that not only the round of the stern may be shown, but the twist may be also shown, and by running in other extra sheer-lines, extending a few frames forward, we may not only show the true sweep of any part of the stern, but the shape of the corner-counter timber. To determine the shape of the cross-seam, we may take the height from load-line on the model to the cross-seam on the several section-lines, and set them off in the sheer-plan; we may

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also apply a square to the cross-seam from the middle-line, to discover whether the after-side is at right angles with the middle-line at the several sections; if it is square from the middle-line at all the sections, the spots already made will rise above each other as much as the cross-seam rises at the respective section-lines, as shown in the body-plan, Plate 5. We may also strike those parallel lines called sections in the half-breadth plan, making the spaces to correspond with those of the body-plan, being also the same section-lines which can be seen in the three plans, viz.: sheer, half-breadth, and body-plan.

Having now the section-lines shown on the stern, their intersection with the cross-seam may be squared down to the half-breadth plan, and the corner of the stern, which is the ending of the sheer-lines, and may be swept in, as seen in Plate 4; this line will show the shape of the corner or margin-line on the rake of the stern, and we may obtain the vertical cross-seam-line by squaring the margin-line down from the sheer-line across the half-breadth, and take the breadths and heights as we would in running in a square frame in the body-plan, where it may be shown. Should there be any difficulty found in securing spots on the corner to carry the sweep from the cross-seam to the

rail, it may be well to run in one or two more section-lines at the parts where the spots are required, and obtain breadths and heights in the same manner as before. We may find a ready mode of arriving at the most difficult parts of the operation by extending the gauge-marks representing the section-lines forward on each sheer-piece; we may then measure the distance from any one of the frames to the edge of the sheer-piece on the section-line, and apply the measurement to the same section, and from the same frame from which it was taken in the half-breadth plan; those spots squared up to the sheer-plan will furnish additional data in proving the section-lines, as they are usually taken from the body-plan and applied to the sheer-plan, as may be seen in Plate 5, by taking the height on the section-line from the base to the successive frames, as they rise above each other; this may be done by the application of a batten, with one edge applied to the section-line, and the square end at the base, when the several frames may be marked on the edge of the batten, and the batten then carried to the sheer-plan, and applied successively to the frames, and the spots marked on its proper frame; this being done, a batten may be tacked to the spots, and the line marked on the floor. If the cross-seam, which is usually called

the back or after-side of the transom, be square from the middle-line transversely, (which is readily ascertained by applying a square to the model,) as far out as the section-lines extend, the ending of those lines as far as the cross-seam is found to be square, will be at and on the same point at the base of the counter when the stern is of the usual form; but as we have shown in Plate 4, they should extend to the rail, and define the round of the stern also. When the cross-seam leaves the square or right-angled-line from the middle-line running forward, and we have no sheer-line at that height, we may strike a perpendicular line square from the base-line to the rail-height, and then take measurements from the model, by first applying a square with the stock in a longitudinal direction on the middle-line, to obtain its round forward at the several sections, and next with the stock of the square in a vertical direction, to obtain its rise above a level or horizontal line; the round forward may be set off from this new perpendicular at the section on which it was taken in the half-breadth plan. This method differs only from the one before described, in that of measuring from aft in the latter case, and from forward in the former. The latter can be adopted when the former cannot. Temporary sheer-lines may be run in

the sheer-plan, and the heights transferred to the body-plan, from which half-breadths may be taken and set off in the half-breadth-plan, crossing as many frames as may be necessary to regulate any particular part of the quarter, buttock, or corner of the stern; but if proper attention is paid to the distribution of lines when making models, this will rarely be required, as no part of the model is unapproachable when separated, if the lines have been properly distributed. Section-lines answer other purposes than the regulating of the round of the stern, as we shall show in its proper place; they are important in laying down and bevelling the transoms, proving, cants, &c.

We have doubtless remained sufficiently long on the after-body to elucidate the manner of transferring its shape to the floor, and of subjecting it to a first proof through the aid of the body-plan. We shall not pursue the course of many builders in carrying this body through a second proof, and commence making moulds before laying off the fore-body as a collateral proof; we believe, also, that diagonal lines can be struck in both bodies to better advantage than in one alone, and as they determine not only the correctness of the work, but the bevelling spots, and to some extent, the length of the timbers, we

deem it most proper to expand the whole ship, and carry the fore-body through the same operations the after-body has undergone, before commencing the second proof with diagonal lines. We have already shown, that the same frames represent both bodies, and having completed the sheer-plan in the fore-body, shall at once proceed to laying off a half-body-plan, and to sweeping in the water and sheer-lines, which are supposed to have been already set off in the half-breadth-plan in the same manner as in the after-body; the half-body-plan will also be projected on the floor in the same manner as that of the after-body, and the battens tacked to the lines in both the half-breadth and body-plan as before. It will be remembered, the lap must be taken from the lines of the after-body; that is, the widths of the frames 29 and ⊗ must be taken from the half-breadth, (where the frames are numbered below the base-line,) and set off 29 on its proper frame aft, which is 69, as in Plate 3, and ⊗ would come on frame 73; were that frame struck in the half-breadth-plan, we shall now be able to determine whether the two bodies agree. If the lap can remain without any material departure from the spots taken from the tables, it is best to make the fore-body agree, or to adjust the fore-body to the lap; but if in so doing, we must alter to any considerable extent, it is best to extend a part of the variations to the lap, and in doing so, we may apply a batten to those frames found on the lap in the after-body; this will assist us in the adjustment; the heights must also be taken from the sheer-plan in the same manner as directed in the after-body, and set up as taken from load-line in the body-plan; level lines being stricken across the plan on which the respective breadths must be set off; the battens in the body-plan being tacked to correspond with the half-breadth-plan, and both being fair; the alteration on the lap making a fair frame in the body-plan of the after-body, we may venture to mark in the lines with white chalk as before, and remove the battens. Section-lines may be run in the fore-body in the same manner as in the after-body; but they are not often found to be necessary in the fore-body, and are not always marked on the floor; they may, however, be continued the entire length of the ship at their location, as we have shown, from the taffrel-rail, as in Plate 4, to the main-rail forward. It will be observed that the heights rise in regular succession in the body-plan, and if a small batten were applied to the several spots showing the breadths and heights, it would form a fair curve, as in Section 4, Plate 2, or as in Plate 5. This may

be done in both body-plans, but should be done with great care, as the regularity of the sheer or sirmarks depend in some measure upon the accuracy of the curve; this course may be pursued on all the sheers and the ending, or the heights of each sheer on the side-line in the sheer-plan, will be the height on the side-line in the body-plan forward; the sheers aft above the cross-seam must be taken on the corner of the stern, and not on the centre. Having swept in those sheers, we have not only the height of every fourth frame, but we have the height of every frame, as all the frames cross those sheer-lines, and as a consequence, the point of intersection is not only the height of the sheer on that frame, but the half-breadth also of the frame. Where discrepancies are found to exist in proving those heights, which it is not necessary to do, it will always be found that there has been carelessness somewhere; in setting off the heights of the sheer in the body-plan, each sheer-line should be set off independent of the other, and all from the same point, then, in case there should be a mistake in one height, the remaining sheers would not be likely to have the same error.

Having now expanded the vessel from the model to its full size on the floor, and lined up all the frames from base-line to rail, we will leave the floor

for the purpose of endeavoring to elucidate the subject of sheering vessels more fully than we have yet done. By many the shape of the sheer of a ship is thought to be of little consequence, so long as there are no irregularities; in other words, if it is only fair, it is quite enough.

By close attention to this matter for years, we can come to but one conclusion, viz.: That in addition to that of the strength of vessels, very much depends upon the sheer for appearance.

The very best modelled vessel may be made to appear like a mere hulk by the manner of setting the sheer. It is a very common practice to set the several sheers parallel to each other, by which means the vessel is made to bear an aspect of sameness that is every where repudiated by men of taste; again, we find the sheer of ships regulated on the principle of an inverted arch; by either of those modes we make the vessel loom up to her full size. One of the great secrets in building vessels is to make a large vessel look small; it is a rare quality, possessed by few, and is the only index furnished by nature to good proportions, and wherever found, is at once recognized by even the back-woodsman if he has studied nature's mechanism. There is something impressive in the appearance of vessels to the man who can burst



the broadest part of the vessel, and from the keel to the gun-deck, the hull was as broad as the beam, and the gun-deck was as broad as the hull. The hull was so broad that it was difficult to tell where the hull ended and the gun-deck began. The hull was so broad that it was difficult to tell where the hull ended and the gun-deck began. The hull was so broad that it was difficult to tell where the hull ended and the gun-deck began.

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present time in ship-building, we have spread our banner to the breeze bearing our motto of *mass for the purpose and proportion* is just the same.

One of the grand objects originally in the mind of the designer was to obtain an ample amount of strength, by transposing the weight of the ends on the middle of the vessel; to be accomplished by giving the ship a form broad enough to accomplish this we made her so convenient for those who managed her, that she was almost perfect for her class.

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which the person who valued, than suffered to in New York.



the bands of prejudice, and launch out on the ocean of nature; his first impressions are strong, and very generally correct, he will discover something wrong, but may be unable to tell what it is, he looks at her shape, she tapers at both ends; the strakes of plank likewise taper; the spars grow smaller at the extremities; in a word, he inquires in his own mind, has not this been the governing principle in the construction of this stupendous fabric? The impression still lingers that there must be a discrepancy, or why the impression? He still looks with eager gaze, when he finally discovers that every part of the ship shows a proportionate reduction at the extremities—but those openings between the mouldings—the secret is out; he may be no mechanic, and, as a matter of course, will not express an opinion, professing to know little about the art. We are too apt as mechanics to look at our work with a prejudiced eye, and consequently are wholly unprepared to judge of its qualities. We would not dare to touch this subject had we not resolved to cut to the line, regardless of the ill-deserved censures we may bring upon us by interfering with many of the hereditary notions of the age in the art of building ships. We have often realized this truth, that it were less hazardous to disturb the person of an individual, than

his prejudices; but having been more or less fortunate (time alone can determine which) in occupying a position from which we could test the utility of many of the prominent features of the present time in ship-building, we have spread our banner to the breeze bearing our motto of *fitness for the purpose*, and *proportion to effect the same*. One of the grand objects originally in sheering vessels was to gain an additional amount of strength, by transferring to some extent the weight of the ends on the middle of the vessel; but it was found, that by giving the ship sheer enough to accomplish this, we made her inconvenient for those who managed her, unless the decks had less sheer than the outside of the ship. The tapered sheer relieves us from this difficulty; the sheer of the wale does not affect the sheer of the deck; and what would be gained from a rank sheer above would be but little, inasmuch as the top-sides are usually of lighter materials, on account of the reduction of weight above the centre of gravity, which is worthy of consideration. We may give the wale all the sheer we desire, and reduce it on the plank-sheer to what we want the deck to have,—the deck, however, need follow the outside sheer no farther than the foremast. This practice is very generally adhered to in New York, and with good

results ; for by so doing, we are enabled to obtain fore-castle room without going between decks ; in addition to which, we may bring the hawse-holes lower, which is also an advantage ; the deck-line may be straightened sufficiently, and yet retain a sheer from the hawse-holes aft, provided the bow is deeper than the stern, which is an important qualification in sea-going vessels. By this arrangement we are also enabled to have a top-gallant fore-castle below the rail, and find a sufficient safeguard above in the chocks, that answers a two-fold purpose—to prevent the loss of men, and serve as warping-chocks as far as required, which is seldom much abaft the windlass. We mean by a tapered-sheer, one that when measured vertically from another sheer, either above or below, measures less at the ends than midships—when at the same time on the flare of the bow the opening will often measure more than midships ; but again, we may have the taper, and still retain a heavy sluggish appearance. There is more life necessary to the appearance of the bow, than is required aft ; hence it is quite manifest, that we must depart from the segment of the circle to obtain it. This lively appearance that we sometimes see, which makes a vessel look as though she would move without the application of propelling power, is only ob-

tained, so far as the sheer is concerned, by making the line quicker at the bow, and less so at the stern. There is in sheering, as in other things on a ship, a certain curve adapted to a certain shape of vessel ; this is only another name for proportions. The object in building ships is to compel them by the application of power to move forward ; and is it not perfectly clear that every effort in appearance, as well as in other things, should tend forward ? and can this be accomplished by sheering ships by the curvature of the circle ? The response must come from every unprejudiced mechanic in the negative. It costs no more to build a ship to appear to be doing what she is really designed to do, than otherwise ; a ship may have a very considerable amount of sheer, and yet not look crooked, provided she is kept low aft. The practice has been adhered to every where, until recently in Europe and America, of making the largest frame the lowest one, or the $\odot$ frame the lowest part of the sheer ; the sheer at the stern should not be much higher than its lowest part to impart this zest so important to the appearance of ships. The wall-sided floating warehouse requires a very different shaped sheer from the ship of thirteen knots by the wind. We repeat the assertion that there is a peculiar shape of curvature adapted to the sheer of

every description of vessel, and its shape is admired or rejected almost at the first glance in the mind of the observer, and indeed, it is so designed by the builder, when he makes mouldings, and colors them to attract the eye of the observer; and with a sheer adapted to the form of the ship, although a mere box, as it regards shape, will be quite a passable ship in appearance.

We have said that there should be a sheer adopted that would suit the vessel; we mean by this just what we say, as much as if we had said that a coat should be fitted to the body of the man who is to wear it. Let two ships be built by the same dimensions, length, breadth, and depth midships, with the same difference in the depth of the bow and stern—the one longitudinally straight-sided, carrying her length on the side-line almost as far as the centre—in other words, let her length be nearly as great along the side as at the centre, thus making a bow nearly straight across from cat-head to cat-head—the second may have an easy side-line, and increase in length on every foot of the side-line to its extremity—will it not appear manifest, that the same curvature on those two ships will not only appear to differ, but will differ widely; the end of the first ship seems to be at the cat-head, while the second is several feet farther forward. On the

first ship the effort is concentrated at the cat-head, while on the second it is transferred to the stem. If the ship first described should have the rise of the sheer extended beyond the cat-head, or at the termination of the straight, across the bow, the whole bow will have the appearance of falling or sagging off. This termination on the other would have the opposite effect; the bow at the stem would appear, as in fact it would be, below the other sections of the sheer. The subject will perhaps appear more clear, if we were to bend a batten from the fore-edge of the knight-head along the heads of the timbers at the lower side of the rail, as far aft as the forward part of the fore-chains, where it may be secured; the fore-end may now be released, and carried out until it comes in line with the side, or in line with its after-end; with the batten remaining in that position, we shall discover, that to raise the sheer the whole length of the batten in the same ratio that it is raised aft of the luff of the bow, would be to lift the sheer above the effort of the bow, and deprive it of the aid of the sheer in centring the effort there. The most casual observer will at once see its effect; it may be seen on many eastern vessels of smaller size—brigs and schooners. These vessels are often built by men who are not in possession of the many

advantages arising from an apprenticeship, and consequently their vessels exhibit a lack in many of the prominent features which characterize American vessels generally. The whole fraternity of New-England ship-builders have suffered loss in their reputation in consequence. The reasons for adopting this mode of sheering, is doubtless to avoid the sni in planking and in the bulwarks; such vessels are an eye-sore to men of taste; but if on the easy bow this continued rise to the extremity appears ludicrous, how much more so would it appear on the ship just described! It will be at once discovered that she might be considered a second edition of the *Dutch Galliot*, or not much ahead of the *Chinese Junk*; hence it is plain that a medium should be observed; the sheer we set on a vessel of the same dimensions as the galliot, would make her appear still worse to us than she now does—that kind of vessel requiring more sheer in proportion to the length than a vessel having easier lines. But although the same ratio of rise that characterizes the sheer from the fore-chains to the luff of the bow, may not be continued to the extremity on the full bow, nor yet only in part on the bow of more regular curve on the rail and plank-sheer, as Section 1 of Plate 3, it may be carried fully out on the very sharp

ocean or river steamer, as in Section 1 of Plate 2. Thus we discover, that what in the one case would be perfectly absurd, in another will be not only admissible, but requisite.

To sum up all that may be necessary for us to add upon the subject of sheering, we may subjoin the following:—The whole expression of the sheer must be concentrated in a single point. The head is the representative of this expression; the tapering spaces between the wale and plank-sheer, and bulwarks between the plank-sheer and rail, have a tendency to draw all the power of effort to this point, and as a consequence, the effect is to make her appear like a thing of *life*.

It may not be out of place to consider some of the most important disturbing forces which have a tendency to cause a departure from the shape shown in the sheer-plan of a ship; a part of those forces are inherent in the form of the ship: others are brought into action when the ship is in motion. In the first chapter, it has been explained, that when the ship is at rest on still water, the total weight of the vessel is equal to the upward pressure of the water, but it does not necessarily follow, that the weight of every portion of the vessel shall be equal to the upward pressure of that portion of water which is immediately beneath it. On

the contrary, the shape of the vessel is such, that these weights and pressures are very unequal, which will appear if we suppose a ship to be divided into sections of equal length by vertical bulk-heads. Assuming the mean of the lengths between the load and base-lines as the length for division; we will also assume these bulk-heads to be water-tight, and the sections to be to a line of flotation equivalent to their weight; it will be found that the forward and after sections draw more water than those sections nearer the centre, which affords the most conclusive proof that the ends of the ship are dependent upon the middle for support. The bow must of necessity sustain the greater portion of this over-hanging weight. Assuming the two bodies to be of equal buoyancy, each side of the longitudinal centre, (which may be adopted with advantage on the most burthensome vessels,) the weight of the bow-sprit, anchors, and often a large portion of the chains, in addition to increased weight of the foremast, yards, rigging, &c., over those of the mizzen, requires extra strength in this section to prevent the ship from hogging; and when these extra means are neglected, the ship is found to have lost her original shape at this extremity. The extra depth forward is well calculated to counteract this hogging tendency found in the for-

ward section of almost all description of vessels; the additional amount of sheer is also an important advantage, and an additional aid to prevent a departure from the form when built.

The careful observer will discover, that this departure from the original shape commences at an early period in the ship's history—much earlier than the casual observer had imagined. We need not wait until a large heavy ship is launched before we can discover a departure from the original shape; unless particular care is taken to place the keel-blocks closer together forward and aft, or the ends of the keel are raised above a straight or fair line, we shall find our ship is (what is technically called) hogged before she is launched. The author has seen more than one ship thus hogged. The moment of launching, however, is the period when the disturbing forces commence operating on every portion of the hull.

It must be remembered that these forces are in almost constant activity to destroy the connection between the several parts of the structure; and whatever working may be produced by their operation, tends very materially to increase their effect, because an increased momentum is acquired in their action on each other.

CHAPTER V.

Parallels to the Line of Flotation, commonly called Water-Lines—Their Effect in modelling—Half-Breadth Plan—Body Plan—Operations on the Floor in Laying Off.

Having, by our expositions from the model, carried our readers to the distribution of the water-lines upon the floor, more properly called parallels to the line of flotation, as shown in, first, the sheer-plan; second, in the half-breadth-plan; and third, in the body-plan, we shall next show the manner of doing the same upon paper. The draught, although obsolete in Marine Architecture throughout the United States, is yet adhered to by *Naval Architects* in both the old and new worlds. Before entering upon an exposition of this part of construction, it is necessary that we should give some practical illustrations, which may be found useful in furnishing data for the formation of the vessel upon a plane; as the draught furnishes the beginner with no index by which to determine the shape of the vessel, as a consequence, he is quite in the dark as to the form in its rotundity, although the draught be before him. Thus it will be perceived that it is necessary to have some experience in a matter of so

much moment, before we are prepared to judge correctly of the shape when spread out on a plane.

The favorite water-line does not furnish a reliable shape, as is too generally supposed. Scientific men both in Europe and America have erred in assuming that the parallel to the line of flotation was the actual line of resistance. This mistake has not been confined to theorists. Practical ship-builders for many years have to a very great extent regarded this as an axiom in the great problem of resistance; but the commercial world, for the first time in its history, has an exhibition of the advantages of scientific and practical knowledge, when operating by different means, (each without the knowledge of the other,) and arriving at nearly the same results by taking opposite courses. The theorists of England have discovered something they suppose to be tangible in relation to the formations of parallels, as adequate to the diminution of resistance on both ends of the vessel; in other words, they

have assumed, that were the several lines of flotation formed in accordance with the formation of the wave, from which they have assumed the propriety of calling it the wave-principle—a name not unworthy of its distinguished author, Mr. Russell—who claims to have discovered and experimented upon it, and which may be defined as a mode of construction, taking its name from the phenomena which takes place in the water, and which are called waves.

Its adherents assume that it may be fairly expected, that he who most nearly imitated those perfect operations of nature, would also most nearly approach to that perfection which is manifested in them. There are various orders of these waves; only two of which, however, act a prominent part in what is recognized as the wave-principle of construction. The first is the wave of translation—the characteristic of which is, that it takes up any light body or particle, lifts it gradually to a certain height, and as gradually lowers it again; having carried or kept the body or particle above the level, from whence it was taken the entire length of the wave, it stops while the wave moves on—like as in a field of grain, the wheat remains in the ground, but the waving moves across the field. Fig. 1, Plate 6, will exhibit the

form of the wave of translation, and also show the relative heights that a particle is raised to; as each successive part of the wave passes a given point. The wave of oscillation is thus propagated: if a body be moved fast through the water, there will be left behind it a partial vacuum, which will be filled principally with the water from beneath by the removal of the part of the pressure at the surface, while that at the surface will be so only by force of the water around, or the contiguous particles, which force is much less; the water then, which is immediately above that which is forced into the vacant space, will fall, and the consequence will be, that an undulatory or oscillating motion will be produced; this motion has been denominated a wave of oscillation, and is that motion formed astern or behind a vessel when she moves ahead. The length of this wave, as of that of translation, depends on the velocity of its propagation, which also depends on the velocity of the moving body. The water being divergent, or tending to various parts from the bow, it follows, that if the acceleration of it were continued by an increase of power on the vessel, it would be found that at the termination of the bow, or at the aft-side of the luff of the bow, there would be a partial vacuum formed, the vessel would settle down and draw

more water, the resistance would at the same time be increased, and as a consequence, there would be a loss of power. Such, however, is not the case aft; as the water from the after-body is convergent, or tends to one point, it may be accelerated up to the stern-post with advantage; for the greater its velocity there, the greater will be its reaction, which will be favorable to the progress of the vessel, and have a tendency to give her an onward thrust rather than have a retarding influence, caused by the vertical motion which may be seen following many vessels as now built.

These waves are found to vary in length in the ratio of their velocity as tabulated, which may be found by reference to any work on the theory of waves; so that when the velocity at which a vessel shall be driven is determined, the length of the bow will be the length of the wave in the table which corresponds to this velocity. The length of the wave of translation, as compared with the wave of oscillation, is as two to three, but as only half of the wave of oscillation is taken, and the whole of the wave of translation, so the length of the fore-body as compared with the length of the after-body, is as three to two. Fig. 1, Plate 6, is a theoretic wave-curve of a water-line. The *genesis*, or formation of

these curves, is as follows: the length of the fore-body as compared with that of the after-body, is as three to two; therefore the whole length of the curve is divided into five equal parts, and three allotted to the fore-body. A circle whose diameter is equal to the half-breadth of the vessel on any line of flotation, (as it seems to be intended for all the water-lines,) is described with its circumference intersecting the middle-line at the junction of the fore and after-body, as in Fig. 1; its circumference is divided into sixteen equal parts, and the middle or straight-line running through the centre of the vessel, is divided into eight equal parts. We have now eight spots on each half of the circle, and the same number on each end or side of the centre of the circle, which also shows the greatest transverse section; square up these spots on the middle-line from the same, and strike lines parallel to the same, extending from each division of the circle to its corresponding division on the middle-line, the lines it will be discovered continue to grow shorter as we advance outward; the points where the parallels cross the perpendicular, are those through which a line being drawn will form the wave-line curve; the curve of all or any water-line of any description of vessel may be formed in the same manner. Fig. 1, however, may only

represent the form for the extremities of the vessel; the middle may be continued with a more gentle curve to any length.

The advantages of the wave-bow are set forth, in the assumption that *instead* of accumulating the water at the stem, where its effect is to give greater support to the ends, and as a consequence less to the sides of the vessel; tending also to decrease the practical stability. It accumulates the water at the sides, and takes it away from the centre; the effect of which is to *increase* the practical stability and weatherliness, while the old form, by accumulating the water close to the stem, carries (with the wind a-beam) the resultant, or the effect of the compound force of the water much farther forward, and therefore requires to have the centre of propulsion, or the effort of all the sail farther forward, to counteract its evil effect, as we have shown in Plate 1; this again requires a larger bowsprit, and the foremast farther forward, which, by increasing the angle of pitch, is injurious to the ship in several ways. Another prominent feature in the wave-principle is, that by bringing this accumulation aft, the centre of resistance of the water and the centre of propulsion, or of the sails, are brought more nearly into the same vertical line or plane with the centre of

gravity,—all of which contributes to economize power and facilitate quickness of turning. It may be well to observe that theory and practice here agree. To substantiate the truth of the latter clause of the foregoing remark, viz., that by removing the greatest transverse section farther aft, and relieving the bow of its irregular fullness under the cat-head, we facilitate the obedience to the helm, provided the bow is also relieved of the press of sail, by arranging the masts a proportionate distance farther aft. Public opinion, however, is not yet prepared for so great an innovation into the stereotyped practices of the age, and of course repudiates any statement to that effect, notwithstanding backed by tangible demonstrations, that ought to settle the matter in an unprejudiced mind.

The adherents to the wave-principle also give reasons for advocating the wave-bow, by examining the subject in a manner divested of that *bias* which usually characterizes the analytical expositions of the propagators of a new system.

Suppose, as we have shown, Fig. 2, Plate 6, to represent the plan of a horizontal section of one side of a bow; it will be seen that it is divided by lines perpendicularly to the keel, and square from the middle-line into equal portions, and that those perpendiculars are drawn

from the middle-line to the outline of the bow, at which intersection another line is drawn from thence to the next perpendicular, and parallel to the middle-line, and so of all the rest. When motion is given to the vessel in the direction of her keel and ahead, each section being alike in length, it will impart to the water it comes in contact with, an equal velocity in that direction; but not only so, each section will impart to the water a velocity in a direction perpendicular to this, or at right angles with it, and different in degree, but in the same ratio as their respective breadths differ. As the velocity in the first direction, or in the direction of the keel, is the same in amount for each section, (they being all of a length fore and aft,) it may be disregarded; but when we consider the consequence of the difference of velocities imparted to the water, because of their difference of breadth, this velocity is very different in degree, as is evident from the fact, that before the water on Section 1 can move its own length astern, and permit the vessel to move the same distance ahead, it must push the water out to *a*, that 2 may advance a like space; after having pushed the water out only the distance 2 *b*, and 3 by the smaller distance 3 *c*, and so of the remaining sections, the consequence of this will be seen in an accumulation of water prin-

cipally on the first section, because the velocities imparted by the sections are less in proportion, as they are more distant from No. 1; so that the difficulty of escape for the water from any section is increased by the accumulation, which arises from the difficulty of escape for the water from the following sections—4, 5, 6—and so on as may be; therefore the accumulation on 1 will be in proportion to the velocity it imparts, together with the difficulty of escape for the water arising from the form of the other sections; and when the velocity of the vessel is great, this accumulation will take place to a greater extent, and cannot be confined to the surface; for if the lower parts of the bow are similarly formed, a like process will go on, differing only in degree; therefore it must be perfectly clear, that the water from Section 1 cannot flow out by passing over the water from No. 2, leaving that water, and the water of the following sections, to act on, and be acted upon, each by its own section; for the whole column of Section 1, including each portion of that column, would have to rise above each portion of the column of Section 2, which is impossible; instead of which, when the vessel is going fast, a stream flows outward from Section 1, with a velocity in proportion to the accumulation, which will be the greatest





(all other things being equal) when the breadth of Section 1 is greatest, or when the form is fullest at that part; and the effect of this current will be to intercept and prevent the pressure of the water on the after-parts of the bow—which would take place were it not for this current.

The prominent objections have thus been given by the wave-principle adherents to the round bow, both at and below the line of flotation, from which we may readily perceive that (assuming the theory to be a correct one) a kind of false or water-bow is found around the full irregular bow, which serves as a regulating medium to adjust the difficulties in shape, at the expense of speed and other important qualities. But their objections are no less feasible to the straight bow, which is deemed more favorable to speed and performance.

Suppose the bow to be straight, as in Fig. 3, Plate 6, from each section of this bow, the water would receive an equal velocity; but as the ship is moving ahead, the water cannot pass off, particularly if she is moving fast; and in proportion to the speed there will be an accumulation at 7, and greater at 6, and still greater at 1, because the accumulation at any one section prevents the outward passage of the water from immediately before it, and throughout afterwards; hence it

follows, that the passage of the water outward from the first section will be most resisted, and an accumulation will take place, though not to that degree that it will before a vessel having a convex bow; for although the water at No. 1 is nearest the bow, yet it must follow that of all the sections farther aft whose columns are equally hard to remove; hence the reason why the water rises higher at this section than on any other, when the vessel is moving fast through the water; and it will be observed that the bow, like No. 3, continues to impart an equal velocity at its termination, to that imparted at the commencement of the bow.

Having given the objections to the convex and straight bow, we will proceed to describe the comparative advantages of the wave-bow; first, by stating the object desired to be effected by the bow of the ship, which is to displace the water sufficiently to admit of the passage of the ship, and to do this with the least possible expenditure of power. It has been seen, that if the bow be convex, as in Fig. 2, Plate 6, the motion will be imparted too quickly, the water will be accumulated at the stern, and the evils already shown will arise; or if it be formed as Fig. 3, the motion will not be imparted gradually, and therefore a rise will take place close forward, only in a less degree.

Hence it follows, that the form which will impart the velocity gradually, (for the more gradual the motion the less power will be required to effect it,) and allow it to subside gradually, must be the best. It will be seen by Fig. 4, that the velocity imparted by each section is greater than that imparted by the one before it up to the centre of the bow, where it gradually becomes less and less to the termination of the same; at the stem there will be no accumulation, and at the after-end there will be no deficiency, and that form will occasion the phenomena called a wave; for though the action of the bow is to move the water horizontally, yet as its outward motion from the bow of the vessel is met and resisted by the water farther out, it can only escape by rising above the surface; and of course the amount of rise will be in proportion to the outward velocity communicated. This is least at the two extremities of the bow, and most at the centre between the stem and its after termination; therefore the result will be a gradual rise from the stem toward the centre, and a gradual subsidence from the centre toward the after termination of the bow, or in other words, a *wave*. This will not only be effected with the least consumption of power, but the better position of the accumulation will have marked a favorable

influence upon most of the properties of the ship.

The principles we have laid down for the formation of vessels, are not entirely new in the old world, although quite new in the United States. Rivalry has given an impetus to improvements in Europe that must set aside the musty folios of the past behind the curtains of oblivious drapery. The British Association have upset the old rules, and are now daring not only to build vessels with hollow lines, but to place the greatest transverse section abaft the longitudinal centre of the vessel. The following proportions which were regarded with favor both in England and the United States, are now being partially reversed—the placing the greatest transverse section two-fifths of the length from the bow, is now being placed aft of the centre of length. As a precursor to those improvements, it is but a few years ago since a daring adventurer took the responsibility of breaking the law of precedent, and without consulting his rivals in the art, placed the dead-flat frame at the longitudinal centre of the vessel. The subsequent action of the British Association, under the direction of Mr. J. S. Russell, have led to very important results. A committee was appointed, whose researches and inquiries have established, by a series of

experiments, not upon the smooth surface of a mill-pond, but upon the ocean, a set of very curious facts. The old-fashioned principle was, that the water-lines should be nearly straight, and that there should never be a hollow line, except a little in the run of the ship, but that there should most certainly be none forward—all the lines on the bow requiring to be convex—and whenever any bold experimenter would refuse to allow public opinion to think for him in this matter, or in that of placing the dead-flat frame farther aft, his success was set down as an exception, and not as the rule.

Mr. Russell claims for himself in Europe, as having discovered the proper shape for the water-lines, which he distinguishes from others by naming it the wave-principle. Experiments in the United States have fully established the practicability of placing the greatest transverse section as far aft as the longitudinal centre of any vessel. It is somewhat surprising that the same difficulties in determining appropriate shapes should have been found to exist by different means. While adhering to the parallel, or to the inscribed line of flotation, and endeavoring to systemize the principle of forming vessels from the form of this line, as shown at the surface, in England, another method was adopted in the United States, that

will, without doubt, prove equally, if not more, successful, because it strikes at the root of the matter. While the theories of the old world only skim the surface, the experiments in this country have been based upon the right-angled pressure, or the equilibrium of fluids. It will be found, that by obtaining the shape of the bow of a ship from the model at right-angles from its surface, we shall discover that this line is much fuller than the inscribed line of flotation; and that to reduce its fullness to that of straight, or nearly so, we make the line of flotation hollow; this may be seen by referring to the dotted line shown in the half-breadth plan of Plate 2, Sec. 1: it will be discovered, that although the load water-line is straight, the line of resistance is quite round, but not sufficiently round to generate a wave at a speed of seventeen miles per hour. It cannot be expected that freighting-vessels should be adapted to high speed, but they may be built to carry all they now do in a much shorter time.

In relation to the wave-principle we will only remark, that the principle is an approximation to nature's standard, but the manner of application is defective; the motions of the water around the vessel are deceptive; the large amount of hollow aft at the surface is wrong, which is evident from

the fact, that it would require more rudder to steer such vessel than one having less hollow. In general terms, we may also add, that the action of the fluid around the bow and sides of the vessel, would perhaps lead the casual observer to conclude, that the revolutions were horizontal and parallel to the surface on all parts. The practice itself would have a tendency to mislead the public mind, and beget and nourish that subtle foe to all improvement, *prejudice*, which, from its very nature, is contagious; it lurks among the labyrinths of thought; it flashes like the electric spark with every glance of the eye; it may be seen at the fountain of knowledge, mingling its insipid properties with every draught—this bane of all progress in ship-building has been borne down in the ship-yard by the commingling influence of interchange. The young operative mechanic finds, that public opinion to the contrary, notwithstanding, he may know as much about putting work together at twenty-five years of age, (even though his father might not have been a ship-builder,) as another who may have lived fifty years, and whose ancestors were ship-builders from time immemorial. The desire of the builders to make money, has fostered this laudable ambition, and *hereditary knowledge* has lost much of its attractive charm

in practical operations in the United States. Not so, however, in the theory of ship-building; this insidious foe is feeding on the very vitals of scientific knowledge, having never relinquished its claim to the hereditary distinctions in the old world, from whence it has been transplanted to the new, and its poison distilled and diffused as widely as our commercial interests have extended. Few minds possess that executive power necessary to throw off the cumbrous mass, and not only assert, but maintain an equilibrium of thought and action.

We have found it necessary to show in a former chapter some of the baneful effects of drawing hereditary distinctive lines of scientific knowledge; but being about to penetrate these illusive dreams by the light of truth, we deemed it due to our readers to show with what rapid strides this herculean monarch has marched over the whole area of the commercial world. Its insidious poison has been diffused not only throughout the ship-yard, in its every department, but upon the ocean, in the counting-house, and at the domestic hearth around the fire-side; thus the thinking man will plainly see that the milk of knowledge has been curdled at the fountain. The man who professes to know nothing of the peculiar properties of models, will show

his attachment for the same form of water-line as his friend, and with an extension of knowledge he will often endeavor to fortify his mind, not with arguments in their defence, but with the *prejudices* of his friends. We have known many whose general impressions would have been correct, provided the first impressions had been directed into a proper channel; but having taken the wrong bias, are led into the prevailing notions.

It is not against prejudice indiscriminately that we wage war; we believe that a certain amount is necessary, and would have little confidence in the mechanic's excelling that had none; but it is that amount that prevents the shipwright from thinking for himself; it is the man who does not set a proper estimate upon his own thoughts, and is unable to shake off the bias that other people's opinions have made upon him, the scales of whose mind are not properly balanced, having a weight always in one side. The positions laid down are not the deductions of theorists, but the result of tangible demonstrations both in Europe and America. Theory and practice agree in the old world, that the greatest transverse section should be farther aft. This adjustment has been practised by the Spaniards, recommended in France by scientific men, and approved by at least one

builder of Portsmouth, England, having had more than fifty years' experience; and last, though not least, America, as far as she has adopted it, has had abundant success, as we shall hereafter show.

We have said that the resistance met by the moving ship was not in the direction of the inscribed line of flotation; we will not descend below the surface until we have endeavored to show this above water. Has not the man who has witnessed the action of the wave against the bow of a vessel noticed that it was thrown off at right angles? Does not our every day experience teach us this, that if a bow has a great amount of flare, the water falls proportionately nearer the vessel than from a bow that flares less? Just so with the stern; from the ship that has flat buttocks, the water will fall at right angles from the same; the shape of the bow immediately below and at the surface, determines the form of the wave generated; the surface is the starting point for every particle of fluid set in motion around the vessel; its course is determined by the shape of the immersed part of the hull; hence it is plain that the direction differs materially from that of the parallel to the line of flotation. It is a truth known to every man that water moves over a perfect plane with the same facility in

one direction as in another, while the pressure is equal; hence it is quite apparent, that the turning of the molecules of the fluid will be in a direction in which the least resistance is encountered. We may suppose a vessel to be supported entirely by musket-balls of less malleable material than lead; let a cavity be formed that will permit a vessel to float; it may be of the form of the greatest transverse section; the balls may be placed under the vessel, assuming the transverse section of the cavity to be exactly the size of the balls larger than the vessel; if the slip, box or dock containing the vessel were of the same form and size transversely at each end, it is quite plain that the vessel would rest only on the $\otimes$ frame, which is quite enough for our purpose; the vessel may now be grounded on the balls, by removing or letting off the water. We now have a row of balls across the cavity containing the vessel, under the keel on its sides, and from the garboard-seam to the load-line; the vessel may now be moved forward, and let our readers watch in their imagination the direction of the motion of the balls—of those under the keel, the axis will be horizontal, while those on the sides of the keel will have a vertical axis; the balls under the bottom will again differ from those sustaining the keel, having a diagonal axis.

It is just so with the water; and this is what we mean when we say the direction of the resistance is not parallel to the lines of flotation, but at right angles with the adjacent parts: this applies to every part of the immersed portion of the vessel. These remarks are designed principally for those who leave the model, and suppose they can make improvements on the floor, or on the draught. It requires but a moment's reflection to satisfy the thinking-man, that when we exchange rotundity in perspective, for delineations by sectional planes, we mistake the shadow for the substance. It is impossible to mark any discrepancy in form only from analogy on the floor; true, by distributing the battens on both bodies, we prove our work, but to determine shape with any considerable degree of certainty, is out of the question. There is scarce a builder who has not his own peculiar notions in relation to the proper form for those parallel planes; one decries hollow lines on both ends of the vessel; another has no objection to the hollow on one end; while a third will advocate the same on both ends; thus the young mechanic is led to suppose, that by following his employer, or some successful builder, he has discovered the universal alcahest for all the mysteries beneath the surface of the fluid.

We will endeavor to analyze the results of this assumption. Were the rotary motion of the particles as assumed by the adherence to the parallel for the water-line, we would find that the axis of every molecule operated on by the moving vessel, would be vertical—a consequence that even the casual observer would repudiate. We can by no stretch of the imagination admit of such direction. It at once destroys the equilibrium of fluids, and annuls every law for the government of the same. The man who models a vessel possessing those views in relation to the parallel to the line of flotation, cannot entertain correct views of the first impressions made upon the fluid by the moving vessel. It would be well for him to make his model by lines running as near at right angles with the exterior surface of the greatest transverse section as may be, and at the proper distance, for determining the required shape.

Assuming that enough has been said in this chapter upon the shape, we shall now proceed to delineate the manner of constructing the draught without the model. It has been the practice of foreign authors to furnish the dimensions of different ships, and at the same time make such expositions upon their various qualifications, as the exigencies of the case may seem to de-

mand. It is not our purpose to pursue a similar course. Were we thus disposed, we should doubtless find a bewildering discrepancy that exists in the proportions of different ships—which would leave our readers still more in the dark.

We have already given proportions for the principal dimensions of freight-ships in the United States. In England the depth has been set down as being proportionate, when it equals from five-ninths to two-thirds of the breadth—the length at four times the breadth—but for speed, Euler found by experiment, that six feet of length for one of breadth, was better than a less proportion. Exceptions to those rules must be made, according to circumstances.

Having determined the principal dimensions, we may now commence the draught, which will be found to consist of three principal plans, called the sheer, the half-breadth, and the body-plan; they are usually drawn in as many separate places on the paper, which should be stretched on a board prepared for the purpose. Although the draught consists of three plans, but two only are necessary to determine the form of the ship; the third may be deduced from the other two.

The usual arrangement, and the one with which the eye has become familiar,

is that of drawing the sheer-plan on the upper part of the sheet, while immediately below, the half-breadth plan is drawn, and the body-plan is drawn either ahead or astern, when the paper is sufficiently large; but when this is not the case, it is sometimes projected on the middle of the sheer-plan. Beginning with the profile or sheer-plan above, we must leave ample room below for the half-breadth plan, which will require more space than the actual half-width of the ship. We shall find it convenient to first secure the paper on the board by gluing the edges down; after having wet the wrong side of the paper, one quarter of an inch of gluing surface around the edge of the paper, is sufficient; it should be partially dried with a warm iron, in order that it may be perfectly so before the paper shrinks much, as the contracting power is very great, and would tear up the edges unless the glue was quite dry. The right side of drawing-paper is the smooth side, or the side from which the maker's name can be read from left to right. The edge of the board should be straight, and at right angles with the ends; we shall find this to be quite essential in working with the T square; the use of which materially facilitates the work in marking straight parallel lines to the base of the board, or lines at right angles with the base.

Begin with the sheer-plan, showing a broad side view of the ship, and in which the lengths and heights of all the lines are shown. The perpendiculars may be erected upon the base-line, and should extend from the margin-line forward at the stem, and on the load-line of flotation to the margin-line on the post, at the same altitude; the base-line represents the upper edge of the keel, as has been fully shown in the last chapter. From the base we may square up a line representing the dead-flat frame, determining first upon its proper location; this we recommend to be about the centre of the space between the perpendiculars in freighting or sailing ships, for the obvious reason that the custom has prevailed almost universally of trimming ships by the stern, which brings the dead-flat frame of the ship (having a long fore and aft floor) farther aft on the bottom than the builder designed that it should be; hence it must be quite apparent, that if the dead-flat frame were placed farther aft, and the ship trimmed nearly upon an even keel, the frame would nominally be in the same place. Upon this point (in this place) it may only be necessary to say, that inasmuch as it is almost universally admitted that the centre of gravity of the ship should be near the longitudinal centre—an admission which puts a quietus on every argu-

ment against having the greatest transverse section in the same place—we may now prepare the half-breadth plan, by drawing a line parallel to the top of the keel, and at the same time parallel to the edge of the board; run down the perpendiculars to this new line, which is the middle-line, showing the longitudinal and transverse centre of the ship; these lines, as all subsequent ones, until our readers are notified, should be marked with pencil only; the dead-flat may also be continued down to the middle-line. Our next course should be to prepare a body-plan, which is designed to show the moulding shape, or edge of all the frames, this plan is made to conform with the breadth and depth of the ship at the dead-flat frame, from the base-line or top of the keel, to the lower side of the rail. After having its boundary line, we may mark in the $\odot$ frame, assuming that it represents the lowest part of the bottom from the base-line outward; also assuming it to be the widest frame in the ship, it is not uncommon to have several frames by the same moulds; this, however, is no advantage, even though the ship may be designed for burden only; from this frame we may determine the location of the several sheer and deck-lines, by setting up their heights above base, remembering that the line showing the top height or the lower side of the

plank-sheer, is above the deck-line, the depth of the water-way, which varies from twelve to fifteen inches. The depth of hold is taken from the top of the beam in the main hatch to the top of the ceiling alongside of the keelson; from this we may be able to determine the required depth of the dead-flat frame, and the proper location for the load-line, for which see page 43. Should we determine to have a projection at the top of the wale, we should at once fix upon the width of the strings, or those narrow strakes immediately below the plank-sheer, and above the wale; thus we are furnished with those sheer-lines—the wale, or first height, the lower side of the plank-sheer, or second height, and the lower side of the rail, or third height. It will be remembered, that when the distance of those lines from the base, or from load-line is measured, they are heights; but when measured to the middle-line, or horizontally, they are breadths. We make this remark, lest we may not be distinctly understood, as this mode of naming sheer-lines is perhaps not generally known even in the private yards. In Europe, the lower or first sheer-line is called the height of breadth, top-height, and rail-breadth, but the course we have adopted is readily understood. We may now set up those heights on the dead-flat frame in the sheer-plan,

and having first swept in the margin-line, or inside of the stem, cutting the perpendicular at load-line, and in its continuance intersecting the base as far aft as the forward square-frame, (for reasons shown on page 118,) thence to the stern-post, the inside of which also cuts the rabbet at the load-line, and from a point near its head, projecting the counter and stern, or the line representing the centre of the same. We may here remark that the point from which the counter projects from the post, is called the cross-seam, from the division which here takes place between the bottom-plank which end here, and the plank above which seam here, and end on the quarters. This division, however, applies to the sterns of ships as they have been built; but we cannot suppose that the practice will be long continued when its defects become generally known. This line of division referred to is, and must necessarily continue to be, the weakest part of the stern. It requires but a glance to discover that this is not only a division in the plank, but that it extends to the timbers which are dove-tailed into the transom; and it must be also apparent, that it is either necessary that the plank from the bottom should extend as high as the upper edge of the counter, thus covering the weaker part, or that the stern-frame should

become obsolete we may adopt either; the cross-seam may for the present be located in its usual place; its height must be determined to some extent by circumstances; but the higher we are able to get it, the better shape we may obtain. The difficulties in locating the ordinary cross-seam high are, first, we are deprived of light between decks, by crowding up the cabin windows; this brings them in range of the deck-beams. Custom has made it a law (and we know of no other) that there must be counter enough to cover the rudder, and something to spare; it has also determined that there must be an arch-board, and that the cabin windows must come above the arch-board. The second objection (which is not an objection in reality) is, that the wale must twist under at the after-end if the cross-seam is high, as in Plate 5. With these remarks we leave the subject, allowing our readers to place it where they please.

We may now hang the sheer-lines at the several heights on the dead-flat frame, and ending for the present on the stern, and on the margin-line forward, which should be continued as high as the rail is designed to be. Our remarks upon sheering in the last chapter will apply here equally well; we will only add, that the amount of sheer is a matter of taste; one quarter of an





inch to the foot at the wale, and one-eighth at the rail for a large ship, can be distributed to look well. Assuming that the sheer-lines have been disposed of, we may now divide that part of the sheer-plan into parallel and equal spaces between the base and load-line; the lower space should be less than those above, because of the advantage obtained in having a line near the base of the bilge, or its lower part; these lines extend from the margin-line forward to the same on the post, and may be marked in with ink; they are usually called water-lines; the base-line may also be marked in with ink; also the stern, counter, margin of post, and stem, as high as the bow-sprit. It may be well to add, that the ink used for mechanical drawings is India ink, and should be mixed by being rubbed on the finger after dipping one end in clear soft water; but a few drops only are necessary to mix at one time, and should be kept entirely free from dust. One of the great secrets in drawing a handsome draught with even or smooth lines, will be found in that of having the ink pure, and cleaning out the pen before laying it down; the insides of the pen must be entirely free from any congealed ink, or it will not work to the satisfaction of a man of taste.

We now have all the longitudinal lines we require at present, and may

next divide the length into vertical spaces, after determining the timbering-room we require, or the distance we resolve to have the frames apart; the fourth frames may now be set off on the base-line each side of the dead-flat frame—this arrangement may extend the entire length of the sheer-plan, but may not be marked with ink beyond the forward and after square-frame; these square-frames are so called, because they not only stand square across the ship, but have a floor-timber attached to them across the keel; as floors cannot be connected with cant frames, they are carried no farther than the square-frames extend. The practice of canting frames from a transverse line across the keel, is found to economize timber very much, this being the principal reason why it was adopted in this country some fifty years ago; the round of the bow and buttocks increases the bevel of the timbers, and as a consequence, renders it necessary to have larger timber to make the same futtock than the cant frame would require; the frame being canted, the futtock may be made of a smaller sized piece. But this is not all; the fastening is distributed to much better advantage on cant, than on square-frames, even of a tolerably sharp vessel. There are exceptions however to this, found on the bow of a very sharp steamer or

steamboat. About the usual proportionate space allotted for cants may be seen in Plate 3 or Plate 7. No determinate space however for the cants can possibly apply to all vessels—the shape of the vessel must furnish the builder with all that his judgment may require—after having set off the fourth frames parallel to the dead-flat, which should be exactly square from the base, or perpendicular to that line; and not only this frame, but all the lines representing frames in the sheer-plan, should be at right angles with the base and middle-lines. One of the simplest modes of raising a perpendicular may be seen in Plate 7, and may be thus described—a base of six feet, perpendicular of eight feet, and a hypotenuse of ten feet, all measured by the scale upon which the draught is drawn, or all by the same scale: the frames should now be named as described on pages 121 and 122, and the heights taken on every fourth frame above the load-line, then transferred to the body-plan, as shown on Plate 7, and described on page 130. It will be remembered, that we have the full dead-flat frame swept in on both sides; one side of this plan belongs to each body: it is usual to place the fore-body on the right, as in Plate 7—this indicating the draught to be what is called a starboard or right-handed draught. We only name

this because the great mass of mechanics are unwilling to step aside from the beaten-track, even though nothing could possibly be lost by it. It makes no difference which side of the body-plan the fore or after-body may be placed; if, however, the stem is to the right in the sheer-plan, it shows the starboard side of the ship, so also the fore-body on the right of the body-plan shows the starboard side: it is the same aft. We may now take off the half-breadth of the load-line on the dead-flat frame from the body-plan, and set off the same in the half-breadth plan—likewise the half-breadth of the several sheer-lines at their corresponding heights in the body-plan may also be transferred to the half-breadth plan; this should not be done with the dividers, but with a narrow slip of paper, as all other transferred measurements should be taken. The dividers are useful in their place, but their points should not be inserted into the draught—the beauty of a draught is gone when it is riddled with holes, which may be easily avoided, and no time lost by using the slip of paper in their stead.

The side-line next demands a share of our attention. This line represents the side of the keel, stem, and stern-post, and should extend in the half-breadth plan from the head of the stem as far

aft as its intersection with the base-line—(we mean by the head of the stem)—in perpendicular line with its head, and in the same manner with regard to its intersection with the base; likewise aft, the side-line should extend from the head of the post, or from cross-seam to the base-line, that is to say—if the post has three feet of rake from a perpendicular line, the length of the side-line should also extend three feet. See page 126 and Plate 4. The side-lines must only be marked in pencil line. We may now square down the intersections of the water and sheer-lines with the margin-line from the sheer-plan to the half-breadth plan, marking a spot on the side-line for each water and sheer-line, both forward and aft. We may now determine the form of the load-line, having its breadth on the dead-flat determined, and its ending partially so, and may spread out half of the moulding-size of the ship on this line. We have already shown that this line is the inscribed line of flotation, and its shape, or rather a shape that will suit us, is doubtless determined sooner or more readily at this part of the ship, than at any other. At the first sight of a ship afloat, (when near enough,) the eye seems involuntarily to run along the water-line, and our mind is often soon made up with regard to the form below water. We are speaking in general

terms to show why we have began here to form the half-breadth plan, and we will farther add, that to those who have familiarized the eye to the water, or parallel to the line of flotation, this will doubtless be the readiest mode of obtaining a form that will please them in its rotundity. What we have already said, and may hereafter say with regard to shape, will doubtless be all sufficient. We have undertaken in these expositions on drawing a draught to show the manner, and not the matter, and further, that we may more certainly make subjects plain that have not been, we are persuaded, that by having the *model*, the *floor* of the loft, and the *draught*, we shall be able to accomplish our object. Hence it will not be expected that improvements will be introduced in the draught when formed by the *eye alone*—this is not the field for improvement; neither are we willing to encumber the pages of this work with a description of the many futile efforts at designing the bodies of ships by mechanical methods, which have in former times been substituted for correct principles: these methods may be found in the musty folios of the past, where it is best that they should remain.

Such methods of endeavoring to compensate for the absence of more correct principles, on which to found

the design of a ship, were supposed to be rendered necessary, whenever the vessel to be built was of too large a size to admit of being conveniently put up by the aid of the eye alone; and consequently, almost every merchant-builder of the old world is in possession of some such empirical system, to enable him to form a design for a ship; whether the ship built after the design so formed possessed good or bad qualities, did not generally enter into the consideration farther than the *crude ideas* of the projector may have guided him in forming it. We say *crude ideas*, because the builder whose judgment is sound enough to enable him to arrange facts and classify observations, whose experience has been of sufficient extent to have furnished him with an array of truths, from which to deduce principles, will abandon all such attempts as futile, and will pursue the study of the *art* in the manner in which it can alone be studied to certain advantage, that is as an inductive science, and his success will depend on his fitness for the task. The mechanical methods alluded to, may be found in different English and French works on Naval Architecture—Steel, Murray, Bouguer, La Pere, Fournier, M. de Palmi, and others, some of which have been copied by later authors.

We have examined the parabolic

system introduced by Chapman, and cannot suppose that its distinguished inventor designed its introduction to supplant the more rigorous application of philosophical principles, as some modern authors would seem to infer. We have been led to this conclusion from the fact that its principles are based on analogy or comparison, determining nothing tangible in relation to its adaptation to laws governing the element the vessel is designed to navigate, and that to enable the practitioner to make use of this method, he must acquire a knowledge of the higher branches of mathematics, to calculate the exponents, as it is a system of exponential formulas, determined from the areas, first of transverse and next of longitudinal sections.

It must appear obvious to the thinking-man, that any method having for a basis the determination of the form of the transverse sections from sectional areas, and from which to base the form of the longitudinal sections, must be indeed *crude*. What has the peculiar shape of any form in a ship to do with determining anything more than the stability, or to prevent her from rolling? But the parabolic system does not even determine this point; and it may be safely said that no system is worthy of consideration that has for a basis sectional lines at right angles with the

course of the vessel when performing her evolutions upon the trackless deep, as we will show in the following chapter.

We have given some of our reasons for determining what shape we require from the half-breadth plan, and may also add, that no man who takes his eye for an index to shape in its rotundity, can possibly tell either in conveyable expositions to others, or portray to his own mind what form his vessel will be from the transverse sections. It was for the purpose of showing what the half-breadth plan really is, that we have departed from the course pursued by our predecessors, who have invariably began with their expositions on the body-plan, and drawn all their deductions from the same. We, however, have only shown the greatest transverse section as a boundary-line for regulating practical stability and determining heights at the several sheer-lines; from this frame we find a boundary-line for the extreme breadth of all the lines in the half-breadth plan; and having the load-line swept in with pencil, we may proceed to form the rail at its lower side, having already the settings-off for the midship-frame and the ends: one or two other water-lines may also be penciled in the same manner. There was a time when this was a tedious process, inasmuch as it required a mould for every line, made of some very

thin, close-grained wood; but lines on any part of the draught may now be readily swept in by the use of weights and battens, which are held to any required form by the point of a wire inserted into the end of the weight, and bent down to the lower surface of the same, within the thickness of drawing-paper of its base. This precaution is necessary, for in case the weight should slip off the batten, the paper would receive no damage from the point, it being too short to reach the paper. The battens may be made of steel, cedar, or ebony—the latter is best—holly is good for battens. The weights may be of lead or cast iron, with a hole *cast* in the heaviest end, into which a plug of wood may be inserted, and afterwards a wire driven into the plug, then the end brought to a point, and bent down the required distance; one dozen weights are enough to draw the draught of any sized vessel. We have found those we use to be second to none that we have seen; they weigh $3\frac{1}{2}$ pounds, measure 7 inches in length, are $1\frac{1}{2}$ inches of parallel width, by 2 inches deep; the hinder end is thin, while the bulk of weight is brought near the end into which the wire is inserted. The sides of the forward end may be rounded off, that two points may be brought near together. The shape is a matter of taste to some ex-

tent. The hole should be oblong, and be *cast* in the weight, inasmuch as the shape and roughness of the hole will hold the plug firmly, which a drilled hole cannot do. Having temporarily swept in one or two lines below the load-line, we may take off every fourth frame midship, as before directed, upon a slip of paper, beginning on either side of the dead-flat frame, and continuing to the bow or stern, near which we may omit but one, taking every second frame: the half-breadth being taken from the middle-line on the frame to be shown in the body-plan to the inscribed line, represented both in the sheer and body-plan. Having thus taken off all the half-breadths of any one line, we may transfer them to the body-plan, and after performing the same evolutions with the load-line and rail, we may bend the batten to the spots, provided a fair frame may be obtained by following the spots; if either of the lines below the load-line should be found to vary, we may note the discrepancy, and try another frame; should the same error be discovered, we may transfer the variation to the half-breadth, and again place the batten to the spots thus altered. Those frames when found to compare in both bodies, may be marked in with pencil—the line showing the form of the vessel at the wale, or the line called first-breadth, may now be taken off from the frames on the body-plan, and transferred to the half-breadth, the after-end running out fair, aft of the last frame taken off. The lower side of plank-sheer or second-breadth, may also be transferred to the half-breadth in the same manner, the after-end running out fair aft of the last frame. Should there be a discrepancy, it may be regulated by altering the frames so as to correspond, by being fair on both bodies. When the sheer-lines, or breadths, load-line, and two or more water-lines, are formed both to correspond with what we have determined to be the proper form, we may venture to run in the remaining water-lines, and regulate the fourth and intermediate frames to correspond with the same. Should we require a given amount of displacement, it will be necessary to determine what amount the present shape will furnish before we proceed farther. It will be remembered, that the calculation need extend no higher than the load-line; and if, after the calculations have been made, we fall short, or overrun the required displacement, we must make such alterations in the form as will furnish the required amount. It will be seen that neither of the modes shown in the first chapter will apply to the draught—they are designed for the model only. Hence it is plain, that we must obtain

the areas of all the water-lines, if we would determine the exact amount of water displaced; but this is seldom necessary, unless the vessel to be built be a steamer, or a river-boat of very light draught of water; for all ordinary purposes, it is quite sufficient to determine the area of say five of the frames from the body-plan, between the base and load-line, one of which should be the dead-flat frame; add the five areas together, and divide by five, which will give the mean area of the whole. The manner of determining the location of such frames as should be selected, may be as follows: divide both the fore and after-body between the dead-flat frame and the perpendiculars into three equal parts—this of course makes four settings-off, one of which is the dead-flat, and another the stem or post—the other two those required; mark in the sheer and half-breadth plans a temporary

frame at those two settings-off each side of the dead-flat. If the settings-off should not come on a frame, or assuming that they come between the frames already swept in, then, after marking the two frames at the settings-off in each body, we may proceed to take them off the half-breadth, and transfer them to the body-plan, from which the areas may be taken; after which, the formula may be thus—let L be the length between the perpendiculars; $A\ 1$ the area of the forward section; $A\ 2$ of the second section; $A\ 3$ that of $\otimes$; $A\ 4$ that of the next section aft of dead-flat; and $A\ 5$ the after section. Then let $A\ 1=218$ square feet; $A\ 2=482$ square feet; $A\ 3=532$ square feet; $A\ 4=480$ square feet; $A\ 5=220$ square feet; and $H=15$ feet, the distance between base and load-line; $L=175$, the length between the perpendiculars; add the areas together thus:

$$A\ 1=218 + A\ 2=482 + A\ 3=532 + A\ 4=480 + A\ 5=220 = 1930 \div 5 = 386 \times 175 = 67550 \div 35 = 1930 \text{ tons.}$$

To which we may add one-eighteenth of the same for the plank, keel, stem and post. This is no doubt as near as we can arrive to the exact displacement from the draught, without entering into the entire calculation. It is true, that if we were to divide the length into a greater number of parts, and take the mean of a larger number of sections, we should arrive nearer the

exact displacement, but this will enable us to determine whether we have enough displacement; and if we have too much or too little we can contract or expand, as our circumstances may require, but we will follow this formula into another shape, and reduce this to capacity; let the plank be added—

$$\begin{array}{l} \text{Tons.} \\ 1930 + \frac{1}{18} = 2037 \text{ tons.} \end{array}$$

From this four-ninths must be deducted for the weight of the ship; we then have

$$\begin{array}{c} \text{Tons.} \\ 2037 - \frac{1}{9} = 1133 \text{ tons,} \end{array}$$

the capacity of the ship. Again, we may perhaps be able to learn something from the rule laid down on page 45, when applied to a body-plan, filled out as Plate 5. Taking the dimensions of this plate from the tables, we have length of keel 100 feet, and of load-line 116 feet, area of dead-flat 272 square feet. The formula may be thus—

Length between keel perpendicular	Length between keel perpendicular	Mean length	Area of dead-flat.	Tons.
100	116	216	272	625

$$100 + 116 = 216 \div 2 = 108 \times 272 = 29376 \div 47 = 625$$

The actual displacement is 620 tons. Thus the reader will discover, as we have before remarked on page 45, that no invariable rule can be given which will either furnish the displacement or capacity with any considerable degree of accuracy. The divisor that will apply on all vessels of nearly the same shape, will not apply to the vessel shown on Plate 5, as will be seen by referring to page 45. The highest number there given for merchant ships is 46; this applies to sharp ships of the usual form. This vessel, as will be perceived, has a low centre of effort, consequent upon her being narrow, and having an easy bilge. It will be remembered also, that vessels having a low centre of effort, have but little stability, without ballast. The import-

ance is at once manifest of knowing how to determine not only the displacement but the stability of vessels. Thus we see, that in the draught we are considering, spread out on the board before us, we can determine nothing in relation to the stability; although we may have good dimensions for the same, yet the shape may be such as to counteract all that we may have gained by good dimensions. Assuming that the displacement and stability is what we require, we may proceed, after running in all the parallel or water-lines in the half-breadth plan, to striking lines parallel to the middle or side-line in the body-plan, as shown in Plate 5. The line next to the middle-line will be numbered 1, and the numbers will increase as we advance outward toward the side. The distance from one to the other, or the space between them, should be regulated by the water-lines in the sheer-plan; that is to say, the water-lines in the sheer-plan show the distance these vertical lines are spaced apart in the body-plan. The same arrangement may extend to the half-breadth plan, showing the lines parallel to the middle-line, and at right angles with the frames; they are usually called section-lines. The reason for spacing them thus is, that when we lay down a ship, we find it advantageous to have no more lines than is ab-

olutely necessary; and by making use of the water-lines for section-lines, we avoid the necessity of having other lines. These lines are shown in the three plans—sheer, half-breadth, and body-plans, but principally required in the sheer-plan. Their utility will be discovered by referring to Plate 4. The shape of those lines is obtained from the body-plan by taking the distance on a slip of paper from the base-line to each frame on the first section-line; mark also against each spot, the number of the frame to which it belongs; after taking off all the frames on the line on which we begin, we may apply the height to each frame in the sheer-plan, between the dead-flat and the post in the after-body, and between the stem and dead-flat in the fore-body. After we have completed the settings-off, we may apply the batten to the spots; the after-end running out fair, the end of the batten forward will terminate on a spot found, by squaring up the intersection of the same line (from the half-breadth plan) with the rail of the same—the sheer-plan already showing the height of the end, when the distance forward is determined, or as shown in Plate 5, by the ending on the curve showing the height of the rail. The same arrangement does not answer the purpose aft, inasmuch as the projection of the stern

partially interferes, although the line will finally end on the taffrail, as in Plate 4. We have said that the aft-end of the batten should be carried out fair, aft of the last frame in the after-body, provided at the same time, the first section-line by so doing will end on the cross-seam; and if we adhere to the old method of having the cross-seam level, and the transom square from the middle-line on the back, the sections will all end in the corner. Those lines, it will be readily perceived, represent vertical planes running lengthwise through the ship parallel to the middle-line. The half-breadth and body-plan may be regulated with a very considerable degree of accuracy by those lines.

It will be seen, by referring to Plate 5, that the first height or the wale, although ending on the cross-seam, does not end in the corner as in Plate 4. And we will here remark, that Plate 4 shows the same line on a plane that Plate 5 shows on the ship, and this is the reason why so little pains is taken to regulate the sheer from the sirmarks, instead of running a rope around a ship, as is usually done. The same discrepancy exists forward, but the departure is not so great on the bow. The careful observer will see, that although the opening between the first and second sheer-lines on dead-flat in

Plate 5, are 3 feet 8 inches apart, and on the cross-seam line measured in the same manner, are only 1 foot 11 inches apart, showing an actual taper of 1 foot 9 inches, yet the opening is actually largest aft when measured by the eye. Again, it will be seen that in the sheer-plan of Plate 4, the opening between the first and second sheer-lines taper enough to be readily discovered, yet when the eye drops down to the half-breadth plan we discover that the wale on the ship cannot run around to the stern-post, although it does on the draught. Hence it is plain that the draught and the ship do not agree; and the question at once arises, why is this discrepancy? It will appear quite plain, that the thickness of the plank midships neither elevates or depresses the sheer, though the plank may be six inches in thickness, while at the end the flare and twist causes the outer edge of the plank to drop below the inner edge; and the edge next to the timbers should range above as much as is lost by the thickness of the plank projecting in a diagonal direction, else the outside of the plank will range below the original design. But this is not all; although the model and draught show the ship as she should appear when the plank is on, it is evident that the additional height required should be added before marking the sheer-lines

in with ink; this may be done by adding the thickness of the plank (which should always be somewhat less on the ends than midships) to the cross-seam line; then level out a line to this thickness from the inside at the sheer-line to the outside of the plank, and mitre a line showing the seam into the timbers; its intersection will be the proper height on the cross-seam line for the wale or first height. The discrepancy at the second height is not so great, in consequence of there being much less twist; the same provision will have the same effect. The same operation should extend to several frames forward of the cross-seam, and on the bow in like manner. Whatever the flare of the bow in the thickness of the plank drops the sheer, the line should be raised that amount before inking in the sheer-lines in the draught—their ending on the stern has not yet been determined. We may see in Plate 4 the section-lines continued above the cross-seam to the taffrail, the round of the stern showing those nearest the outside to be forward of those nearest the centre. This course is not generally pursued either on the draught or on the floor. Again, in Plate 5 we may see the section-lines ending on the cross-seam line, leaving the space above a blank, or as the ship is found to be after the frames are all raised.

We have already shown that the sheer-lines may end temporarily on the centre counter-timber; we may determine the amount of round, or how much higher the taffrail should be at the centre than at the side of the ship; this being done, and the number of inches set up square from the sheer-line, we may run up the centre counter-timber to the required height; this point may now be squared down to the middle-line of half-breadth plan, and the round thwart-ship, or across the stern, may then be also determined; and where the sheer-line showing the rail in the half-breadth plan crosses the line for the round of the stern, that point may be squared up to the sheer-plan, and is the ending of the third breadth in the sheer-plan, or the corner of the stern at the rail. It is not necessary that the first and second breadths should terminate in any line across the stern. The arch-board may be set off on the centre counter-timber, and its round determined in the same manner as that of the rail, by squaring the centre down to the half-breadth, and giving it the same or more round than the rail. If the stern has no twist, and the arch-board has the same round as the rail, the lines on the stern in the half-breadth should be parallel to the line showing the taffrail; if, on the contrary, the stern has more or less twist, the second breadth may be continued across the stern, as in the half-breadth plan of Plate 4; and its intersection squared up to the sheer-plan. The corner of the stern may now be shown by drawing a line touching the two spots already furnished, and continuing as low as the upper edge of the arch-board; from this point it may be continued down, out of wind with the centre of the stern, or the same proportionate amount of twist may be continued and obtained by running in a temporary sheer-line, or to remain if deemed necessary. If the cross-seam has any rise, as in Plate 3, 4 and 5, the outer section-line, as in Plate 4, will give a spot for the quarter; and another section-line may be run in, which will furnish all the spots that we may require. It is not necessary to show how to run in an additional sheer or section-line; the same course must be pursued with all lines of the same denomination, whether temporary or permanent; and having been shown, it is not necessary to repeat the operation; what lines we may have found necessary to run across the stern, between the arch-board and rail, will not be required for permanent use, and must not be inked. The stern for the present requires no more lines running across, either in the half-breadth or sheer-plan, than the rail, arch-board, and cross-seam. The cabin

windows may be shown in the half-breadth plan, also in the body plan. We may before proceeding farther, bend a batten at the heads of the frames, cutting the exact crossing of the frame with its own leveled height, stricken across the body plan;—one end of this line in the fore-body is at the height of the dead-flat frame, and the other at the height of the margin-line in the sheer-plan, set up in the body as taken from the sheer-plan. In the after-body the line begins at the same height as in the fore-body, viz., the dead-flat frame, and continues cutting the heads of the frames until it reaches the cross-seam height, from whence it crosses the stern and ends on the middle-line, at the height of the centre of the taffrail, as in Section 4 of Plate 2, and as shown on the stern in the sheer-plan, Plate 4. We may next proceed to strike in the intermediate frames, both in the sheer and half-breadth plans, and take off and sweep them in the body plan. It may be fairly assumed that the draught is proven; although there are more lines yet required to complete it in all the plans, yet the water and section-lines agreeing with the frames, and each making fair lines, there can be little doubt but that the lines will prove in every part if sufficiently near each other. The operation on the draught requires to be somewhat different; on the latter the diagonals are not required for proof lines, although sometimes used; but in the operations on the floor, the arrangement is made as soon as the water-lines are proven, for by arranging the angles of the diagonals in the body plan to suit the length of timber the builder may have, the butts are arranged so that the shape of the timbers may not be very difficult to find. This operation requires some considerable degree of skill to regulate the various crooks, that there may be no timbers that cannot be obtained, be the shape of the vessel what it may. We have not designed the draught to exhibit anything more than the manner of performing the operation, of showing the effect of a tapered sheer, and of arranging the several plans on one entire plane; whereas the operations of the floor by sections, showing the ship in two or three lengths, could not (it was presumed) be as easily understood without this connecting link; nor was it designed to put in all the lines belonging to any one section of the ship, throughout the entire work, for the evident reason that we have not undertaken to exhibit pictures, but to illustrate not only principles, but the manner of working by them; hence it is evident, that the fewer the number of lines beyond what is necessary to show that for which the

engraving is designed, the more easily understood.

Having shown the effect of shape, first, from the model in its rotundity, and following this by expositions on the floor, in sections adapted to the length of the mould-loft, and again showing the general outline of the several plans on the draught, from which we shall now deduce some leading principles that should govern all constructors of vessels designed to navigate the ocean, it will be discovered, that on Plate 7 we have shown the form of the inscribed line of flotation the draught above would delineate when immersed to her load-line, and careened fifteen degrees from the upright or position of rest ; the two sides being marked, it will readily be discovered that there is a material difference in their form at the ends, although of equal breadth mid-ships. Though we have never seen this plan appended to a draught, it does not follow that it should not be. The builder or constructor who does not know what is the shape of the careened line of flotation of the ship he is about to build, does not know as much about her steering qualities as he supposes, however well he may be satisfied in his own mind of her performances in this particular. It will be seen that the lee-line of flotation is fuller both forward and aft than the weather-line,

and although this line on either side only determines the course of the fluid at the surface, it is an index to the shape, both above and below this inclined line of flotation. Those who will take the trouble to compare this inclined form of water-line with that of any of the European packet-ships out of this port, will find that there is much less difference than can be found among freighting-ships, subject of course to exceptions, which are very rare.

It must be apparent to the thinking-man, that with a difference in the form of the weather and lee-lines of flotation, as in Plate 7, the ship will carry a weather-helm. Seamen find that the water acts with more force on the rudder of a ship about half way between the greatest immersed line of flotation and the base-line, than it does on other parts ; and the reason will appear obvious, for it is only at that part of the rudder that the lee-lines of the ship form a suitable conductor to the rudder with the least disturbance. The whirling impulse imparted to the globular particles of fluid, show that they cannot be restored to their buoyancy by any sudden change of direction. When the ship is careened about fifteen degrees from the upright position, it alters the course of the water at the surface of the anterior as well as that of the posterior part of the ship, and when

thus inclined, the distance on the line of flotation from the greatest transverse section to the rudder being much shorter on the windward than on the leeward side, it follows as a consequence, that the water comes directly to the rudder on the windward side in a steady current, while on the leeward side it acts precisely as it does in the river where the current or tide sweeps by the end of a pier with great force, while below the pier, and between its end and the shore, the current is setting up, or in an opposite direction; the consequence is, that the cavity between the quarter and the rudder is filled up from below on the lee-side. We have measured some fine ships in other respects, sailing out of this and other ports of the United States, that had eight feet of difference under the quarter in their weather and lee-lines of flotation.

It must be apparent that the pressure consequent upon the current (formed by the moving ship) on the two sides of the rudder, being unequal when the helm is midships, the lee-bow being also the fullest, which tends to push it around to windward, when the ship is brought to the wind, and to avoid this the helmsman must keep his helm up until the two forces are equal, when the ship is again on her course. The effect of this inequality on the bow is to bring a

vessel to the wind; the surface on the leeward side of the keel being the greatest, it follows that the pressure against the lee-side is also the greatest, and to be relieved, the bow seeks an equilibrium by inclining to the windward side, where there is less resistance. Careening a ship of the ordinary model has the same effect upon the steering qualities, that it would have to move the stern-post aside one, two, or three feet from the centre of the vessel, and terminating all the lines there, and then sailing her in an upright position. Why is it that we do not perceive any difference in the scudding-ship, or that she does not require the helm on one side more than the other? The reason is at hand—the pressure on the two sides of the rudder is equal. Hence the reason why mariners complain of vessels steering bad before the wind; they veer from their course until they receive the wind from the quarter; this causes them to careen, and as soon as an inclination takes place, the water ceases to act with the same amount of force on the leeward side, and acts with increased force on the windward side; consequently she is steady for the moment, but as soon as the helmsman brings her to her course, she performs the same freaks again.

We might point our readers to ships

in different parts of the United States, calling many by name, upon which these deformities would be found, but it is not the province of marine architects to depreciate the value of any man's property by pointing out its defects in a work of reference like this; naval architects can do so with the utmost propriety, inasmuch as an exhibition of the defects of government vessels injures no one. The shape of the ship shown in the draught, Plate 7, is such, that the two lines of flotation would cause the ship to steer remarkably easy, and with less of the weather-helm than is commonly met with in sailing-ships, although the first water-line is somewhat fuller than is usual; and if a model were made by this draught, a majority of builders would tell us that she would not steer; and when public opinion is prepared to look naked *truths* in the *face*, it will be found that the very shape that has been repudiated on account of bad steering, is the shape above all others that steers the best.

It will be observed, from what has been shown, that it is the half-breadth plan that delineates the form of vessels in all the variety of positions that may be requisite for adapting them to all the varied circumstances to which sea-going vessels in particular are subject. The direction of the vessel through

the water is longitudinal, and all that can pertain to the development of the best form for speed, burthen, or performance, must be shown by this plan; not only the several sheer and water or parallel-lines, whether showing the vessel upright or inclined, but the diagonal-lines are also shown in their rotundity; and from no other plan can we form a just conception of the actual shape of the vessel when on a plane, and not lifted up by the laws of geometrical perspective. However important the half-breadth plan may be, the body plan is not entirely destitute of claims upon our attention. Although no just conception can be formed of the shape of the vessel from this plan, yet it cannot be dispensed with, while the present method of constructing vessels meets with popular favor. The actual form of all the transverse sections may be shown in this plan, and the bevellings of the timbers may also be obtained. The body plan of the draught, shown in Plate 7, represents the frames falling within each other, as they would appear to the eye of an observer were he to take a position astern of the ship, his eye in line with the keel transversely, and with the load-line vertically. Assuming the after-body from ⊗ on the larboard side to be left out, this view would show the star-board quarter and the larboard bow;



scantling at the heel of the first futtock on dead-flat give for throating at the forward and after floor? See Plate 8. Making a spot at each of the three frames above the base in the sheer-plan, and one in the middle of the fore and after-body, thus we have five spots showing the height of the throats of the floor, to which a batten may be applied and made fair, continuing out fair to the stem and post; we may now run another parallel to this, cutting the base at dead-flat, and extending from the fore-side of the forward floor to the aft-side of the after floor: this line represents the seats of the floors, and may be formed on the keel, or placed on the keel in an additional piece. In running

the line for the throating of the floors, we should have reference to the keelson, and not get so much hang to the line that we will be unable to get a keelson piece that will set down, as the keelson should run out and form part of the dead wood, and what additional dead wood we may require, may be placed above the keelson. It is seldom however that more is necessary forward than a large stemson or knee, and if the stem has a very considerable rake, straight timber will answer every purpose, and be equally as strong, if so arranged as to cause both ends to have the same bevel, and we may fill up to any required height in the same manner.

CHAPTER VI.

Diagonal Lines—Their Use—Mathematical Demonstrations in Modelling by Diagonal and Water-Lines, discovered by the Author—Their Superiority over the Present Mode.

In Europe it has been the practice to make use of two kinds of water-lines, not only on the draught, but on the floor of the loft—the one parallel to the base-line, the other parallel to the inscribed line of flotation. This practice has been coeval with that of so forming the bodies of vessels as to cause them to draw more water, or to swim deeper aft than forward. As a consequence, the form of any two longitudinal lines that had the same altitude midships, differed in proportion to the difference of the draught of water at the two ends of the vessel; and if a displacement equivalent to the weight of the vessel were obtained below a line parallel to the base, (while the vessel was leaner aft than forward of the longitudinal centre,) it was found that the inscribed line of flotation was not shown on the draught. If the vessel drew more water aft than forward, the line of flotation was fuller aft, and easier forward than the water-line shown on the draught. Experience, however, has taught mechanics in one-half of the world at least, that a form of construction requiring a very considerable difference in the draught of water is no advantage to the performing qualities of such vessel; hence the reason why we find the vessels of more modern build drawing nearly an equal draught of water. Even the far-famed Baltimore clippers, some of which drew sixteen feet of water aft, and eight feet forward, are brought within from one to two feet of difference in the draught of water of the two ends; and the time is at hand when inches will be substituted for feet in this particular. Thus we perceive that two sets of water-lines are no longer rendered necessary, either on the draught or on the floor. Diagonal lines have been designed to answer a three-fold purpose—First, to show the boundaries of oblique planes passing through the ship longitudinally, and meeting the middle-line its entire length, parallel to the base-line. Their second use has been found in the aid furnished in arranging the lengths of the timbers form-

ing the frame of the ship; and the third particular in which they have been found useful, is for proving the water-lines, and for bevelling spots, or convenient and suitable localities for applying the bevels.

The position of the diagonal lines in the body plan where they are first drawn, is not, however, arbitrary, because it has reference to two considerations in particular—the length of the timbers, and their shape. It formerly was the custom, and is still, to some extent, to place the ribbands by those lines, but experience has shown that it is not absolutely necessary; although the ribband would be more likely to fit the timbers upon a diagonal line than elsewhere, because of its being at the identical spot where the body was proved, and where the bevel was applied, and so far as this goes, it is the most suitable place; but if the necessary pains were taken in proving and fairing the bodies on the floor, and an equal amount of care taken in moulding and bevelling the timber, it would make little difference where the ribbands were placed for regulating and keeping the ship to her proper place when raised. Plate 9 will illustrate the manner of arranging the diagonals in the body plan. It was formerly the custom both in draughting and in laying down vessels to expand the diago-

nals when taken off in the direction in which the line run in the body plan, and this mode is to some extent yet in use. It may answer the purpose very well where a sufficiency of floor room can be obtained, but cannot be adopted where floor room is limited, as in this city, and in most private ship-yards. It was from the diagonals swept in this manner that the bevels were obtained from the half-breadth plan before it was discovered that they might be taken with more accuracy from the body plan. The lines were taken off according to the old method, by taking the distances from the middle-line in the body plan (in the direction of the diagonals) to the frame about to be transferred, and setting off the distance thus taken on the same frame in the half-breadth plan. This, as it will be readily perceived, causes the lines to extend further out from the middle-line in the half-breadth than any of the lines taken off horizontally, particularly those in the vicinity of the bilge of the vessel. For the ending of those lines when taken in the angular direction, the height must be taken from the base-line in the body plan to the intersection of the diagonal with the side-line; let this height be transferred to the sheer-plan, and marked on the bearding-line, and from thence squared down to the middle-line of the half-breadth plan, and set-



ting off the thickness of the plank inward from the side-line in the body plan, as shown by the dotted line in Plate 9. The height of the point at which the diagonal crosses this dotted line, must also be taken, and set up on the margin-line of the stem or post, (provided the line we are now ending does not come above the head of the post,) from whence it must be squared down with the former to the middle-line of the half-breadth; take the distance from the middle-line of the body plan in the direction of the diagonal to the dotted line, (which shows the thickness of the plank,) and set this off from the middle-line of the half-breadth upon the forward spot just squared down and marked *a* in the half-breadth, and the distance from the middle to the side-line in the direction of the diagonal; set this distance off from the middle-line of the half-breadth on the after spot marked *b*. It will be discovered, that this operation makes the stem and plank appear thicker than they really are; but when it is remembered that any piece of timber measures more on the angle than on a square, the wonder will cease. The diagonals we have been ending are taken off and applied in the same direction in which they are seen in the body plan. The lines are taken off from the body plan by taking a thin batten and applying one

edge to the diagonal line to be taken off in the body plan, keeping one end to the middle-line, and then marking spots on the batten at the crossing of the several frames; when the frames are all taken off on one line in the same body, they are set off in the half-breadth in the same manner as water-lines are. In the draught, they are shown also in the sheer-plan, for which purpose they are taken off in the body plan perpendicularly from the base to the crossing of the frame and diagonal, and set up in the same manner in the sheer-plan on the corresponding frames upon which they were taken from the body plan.

This method is still practised in Europe, but has long since been repudiated in the ship-yards of the United States; and there are ships built that when regulated on the floor or on the stocks exhibit as few discrepancies as those of the Old World. We say that neither the expanded diagonal in the half-breadth, or the horizontal representation in the sheer-plan, are absolutely required on the floor of the loft to fair the body of a ship; and we have laid down vessels without using even diagonals, and the vessels when raised exhibited as fair a frame as could be desired. These, however, are exceptions to the general rule, and will only apply to very sharp vessels or steamboats;





and when such course is adopted, great care must be taken in the first proof with the water-lines. The present mode (and doubtless the very best) of proving the body by diagonal lines, after having been first made fair, and proved by water-lines, is to take all the settings-off from the body plan horizontally from the middle-line to the crossing of the frame by the diagonal, as shown in Plate 9; that is to say—begin with dead-flat, taking one diagonal, and rise as the diagonal rises, keeping the batten horizontal or parallel to the water-line, and when all the frames, or all the fourth frames, are taken off on the batten from one body, transfer them to the half-breadth in the same manner that a water-line is set off: the ending of diagonals when taken off horizontally differs from the ending of those taken off to their full size. The height at which the diagonal crosses the side-line in the body plan is carried to the sheer-plan, and a spot marked on the margin-line; this being squared down to the half-breadth on the side-line furnishes us with a spot from which we proceed in the same manner as if ending a water-line, by setting off the thickness of the plank on the compasses, and placing one leg of the compasses on the spot just made, and the other toward the end of the ship at which we may be working; resting on the last

leg placed on the side-line, we may sweep a quarter circle with the first leg, and on this circle the diagonal will end. Under some circumstances it may be found necessary to seek another proof to the work; in such case we have only to take off the heights at which the diagonals cross the frames, which are taken from the base-line in a vertical or perpendicular direction, and set off in the sheer-plan; the endings are also taken from the body plan, and are found in the same manner, by taking the height from the base-line to the crossing of the side-line by the diagonal. This height applied to the sheer-plan, and marked on the bearding-line, furnishes all the ending required, inasmuch as the direction of the line will show the height of its final termination on the margin-line; and when the diagonal lines are swept into the expanded size in the half-breadth, we may adopt this last method of ending them, and if there should be any difference, take the ending that carries the line farthest in; that is to say—let the height be taken on the side-line in the body, and applied to the bearding-line in the sheer-plan, thus showing a spot on the bearding-line in the sheer-plan the same height as the crossing of the side-line by the diagonal in the body plan. Having swept in the diagonal in the sheer-plan, as in Plate 9, the

end running fair across the spot on the bearding, and continuing to the margin-line, then square down these two spots to the middle-line of the half-breadth; take also the distance from the middle-line of the body plan to the side-line in the direction of the same diagonal on which we are at work; apply this distance on the outer spot, or the one squared down from the margin-line; take now the thickness of the plank in the direction of the same diagonal as shown in the body plan; open the compasses to this diagonal thickness, and place one leg on the spot squared down from the margin-line, and the other toward the end of the vessel, (on the same side-line, or the same distance from the middle-line,) and resting on the last leg, sweep a half circle inward, the diagonal will end on this circle, and cross the spot squared down from the bearding-line, if the work is done properly.

We have now shown the several methods of ending the diagonals, whether swung off in the diagonal direction, or taken off as they now very generally are, in a horizontal direction, and ended as water-lines, and shall next show how they are ended on the cross-seam when they come above the head of the stern-post: First—if the diagonals are to be swept in as swung off, they should be continued in pencil-

line above the cross-seam in the body plan as high as the middle-line on the draught, as shown by the dotted line in body plan of Plate 9. Take the distance square from the middle-line from where the diagonal cuts the cross-seam, and set it off in the half-breadth plan square from the middle-line; through the spots thus obtained, strike lines square from the middle-line; then take the distance on the diagonal in the body plan from the middle-line to the cross-seam, and set off from the middle-line in the half-breadth on its respective line already squared up: the spot thus made is the end of the diagonal. This striking a line square up from the spot pre-supposes the cross-seam to depart from a perpendicular to the middle-line, either forward or aft. When the diagonals are swept in horizontally, as already described, those ending on the cross-seam are found by taking the distance from the middle-line in the body plan to the crossing of the diagonal, square from the middle-line, and applying this distance in the half-breadth on the cross-seam in the same manner; and for the ending in the sheer-plan of those lines, we have but to refer to the ending of section-lines on the cross-seam, simply by taking the height from the body plan, at which the diagonals intersect the cross-seam, and setting up the same in the sheer-plan, which will

also furnish an additional proof spot for sweeping in the cross-seam in the sheer-plan. Diagonal lines taken off in this manner are called horizontal ribbands; they are far superior to the extended mode for all practical purposes, and we are unable to discover the reason why they are not universally adopted in Europe.

In laying down a ship there are certain points that will serve as an index to test the accuracy of the work; these may be found in the harmony that will prevail (if the work is properly done) between the diagonals and the breadths. It is quite common for the breadth and diagonal in the body plan to cross the frame at the same point. Care should be taken to see that they cross at the same point in the half-breadth, or ferret out a reason why. We may safely assume that the ship is fairly proved on the floor, if the diagonals agree with the water-lines; and as it will be necessary to run in section-lines for some distance from the ends, particularly the stern, to obtain the bevelling of the transoms, we fairly conclude that there has been a sufficiency of proofs to insure the fairness and accuracy of the work; and having stricken in all the intermediate frames across the body and sheer-plans, we may regard the work as having been subjected to a second proof on the floor. The diago-

nal line is found to be useful, not only as a proof line, and for the better distribution of the sirmarks, but it aids in the planking of a ship. By following the sirmarks we are enabled to make a proper distribution of surface, and reduce the opening in due proportion, before we may have proceeded far enough to make a division of the same.

It must not, however, be supposed that the form of a ship is consequent upon the form or direction of any particular line or set of lines; on the contrary, it matters not what is the direction of the lines that exhibit the form of the vessel: they can run in any direction the builder may choose to direct. Hence the reason why we have shown other directions, as in Fig. 16, in order that the eye may not become so completely wedded to one form of line (which brings a particular shape) that we cannot depart from it. We have no desire to break down the rules and usages universally recognized in this seemingly complicated art. It is only against their trammeling influence that we raise our voice. It will appear quite clear that there is danger when ship-builders themselves tell us, that their eye is circumscribed by a certain shape. How important then that the young mechanic should be entirely free from these iron bands of habit! When studying the laws of motion and utility,

experience is vastly important we admit, but there are a thousand things about a ship, from the false keel to the truck, and from the end of the flying jib-boom to that of the spanker-boom, that the most experienced have never been able to give a why or a wherefore; and we deem the time well spent by the young man who will stop to think and inquire before he makes sail at random, and steers in the wake of his predecessors.

It has been assumed by judicious American writers upon the subject of building ships, that were the *science* to make no farther progress than it has already attained, it is evident that it is so far perfect as to be available for, and capable of, being made to keep pace with the wants of mankind. We, however, dissent from those elevated views, although apparently on the eve of a most important era. It requires but a removal of the frowning influence engendered by the indifference manifested by the Government of the United States to the advancement of commercial science, to convince the world that the science of building ships is yet in its infancy. Individual efforts to improve the shape of vessels for commercial purposes can only be sustained by national efforts. Unlike other improvements, that can be patented, and the advantages secured to the

rightful owner, every improvement in the form of vessels is common property. Shape in vessels cannot be secured by patent laws; hence the propriety of the fostering influence of Government to sustain improvements.

The mechanic may spend the flower of his youth; he may waste the vigor of manhood, in maturing (from experience as well as from the laws of commercial science) the synthetical composition of the perfect ship; he makes known his improvements; the world is benefited, and he dies forgotten, as a dream. Hence we infer that it ought not to be expected that the science of building this stupendous fabric should keep pace with other improvements of this improving age, without the assistance of the fostering care of the Government; but strange to tell, notwithstanding the many millions of dollars spent in building Government vessels, Marine Architecture is at the present time in advance of Naval Architecture. We have been led to offer the above considerations before entering upon the disquisition of a subject, for the introduction of which we have set apart a portion of this chapter.

It has been the object of numerous men of science (who have devoted the whole or a portion of their attention to the various problems embraced in the theory of ships) to define, either by the

aid of mathematical demonstration, or by experimental induction, the various properties of a ship, from which we may fairly conclude that few of its abstract principles remain uninvestigated. Efforts, however, have not ceased to bring something tangible from the science of numbers that shall, to some extent, set experience aside, by placing it in the back ground. An idea has prevailed in the mechanical world, that scientific knowledge was reserved for the comprehension of minds of more than an ordinary calibre. We apprehend this to be a great mistake; the term *science* may be applied to any branch of knowledge that may be made the subject of investigation, with a view to discover its first principles, as distinguished from *art*. A *science* is a body of truths, the common principles of which are supposed to be known and separated, so that the individual truths, even though some or all may be clear in themselves, have a guarantee that they could have been discovered and known, either with certainty, or with such probability as the subject admits of, by other means than their own evidence. In its most restricted sense, it is but the ability to give a why and a wherefore for our daily practice, or, as has been already observed, *proportion*, to effect the object designed; and we hesitate not to venture the as-

sertion, that proportion is to the scientific Ship-builder what the fulcrum is to the lever, or the axle to the pulley—it is the basis of all *science* in mechanism. The man of observation has but to look around him, and he will discover that nature's beauty consists in proportion; it is universally diffused through all her works, from the glow-worm that lights his path, to the rain-bow that spans the heavens. The absence of this all-important quality has wrecked the fairest prospects of many an artizan. This is a shoal laid down in no mechanical chart; and upon no branch connected with the construction of this ponderous fabric, is the mechanic more at loss.

It must be admitted by all who will take the trouble to think, that a ship is actually stronger than another when, upon a trial of strength, the first would break in every part at the same time, while the second would be found much stronger in some parts than in others, even though all the parts of the first example were adapted or proportionate to the weaker parts of the second example. This, to many, may appear most absurd. There are some even in the mechanical world, who suppose that if a vessel, or a particular part of a vessel, looks heavy, that it must of necessity be stronger than another having less of the large, heavy appearance,

This error has proved fatal to thousands in the mechanical world ; but we stop not here. Proportion is equally as well applied to the science of numbers as to mechanics ; and it should not be forgotten that the science of building ships embraces the science of numbers or proportion, which in geometry or arithmetic is the similitude or equality of ratios. There are several denominations of proportional quantities in this science : only one of which, however, stands connected with the subject claiming a place in this chapter, viz., direct proportion. Plate 10 furnishes an exposition of the manner of determining the form of all the lines of a vessel below water. After having first settled upon the form of the first frame, or the dead-flat frame, and next upon a diagonal line that will be found to show the largest space between the frames, as in Plate 10. The direction of this line would, in a majority of cases, be found to range from the middle of the bilge to the cross-seam at the middle-line. We may now determine upon the form of this line in its extended direction, after having swept in the dead-flat frame. It will be quite unnecessary to descant upon the proper form for this frame. As there are such a variety of conflicting circumstances, that each in its turn demand our attention, the reader would, after

all our expositions, be left to determine its form from his judgment or experience ; and the forms we shall furnish in connection with a description of their appropriate qualities, some of which have been already described, will be all that will be required. Having the form of the greatest transverse section, and the form of the diagonal in the direction we have shown, our next business is to determine the form of the remaining parts of the immersed portion from these.

We are aware that some persons have strenuously contended that the entire ship may be formed by calculations, but we are content with blending practice with theory, as a restrictive barrier against encroachments. That a ship may be formed entirely from calculations, or by the use of figures, does not admit of a doubt in our own minds ; but what is to be gained by departing from what we have proved to be available, is a question that has not been answered. We may determine the entire ship's form by theorems ; take the parabolic curve, and we have in it the form of the diagonal line, of which we have spoken ; take Mr. Russell's wave-line, and we have the form of the water-lines mathematically determined ; and again, we may find an hundred ways of sweeping in the dead-flat frame. These modes have

been resorted to in the Old World for centuries, and what has been the result? Vessels built under the old system in Europe are far from being the easiest vessels in their motions. It cannot be denied that American ships, (their principal dimensions being considered,) are the easiest ships afloat. With an almost universal low centre of effort, they are the wonder and admiration of the whole commercial world. It requires no mathematical demonstration to prove that the mid-ship section should be straight from the keel outward, beyond the quarter breadth, to give stability to a narrow ship. It requires no second demonstration of the same kind to convince us that the wall-sided ship will roll farther than the vertically round-sided ship, other things being equal; hence the reason why we are unwilling to change our anchorage, when we know we have good holding bottom for another that we know less about, and this too merely for the sake of change. The system we are about introducing carries with it indelible proofs of its utility and perfect adaptation to all classes of vessels, and while it provides for the bottom, it is applicable to any desired form above water. In Plate 10 we have taken the topsides of one of the packet-ships, and it will be seen that they blend harmoniously. Hence

we say that it will adapt itself to any form, not because it is adapted to the form we have shown, but because we have made the application to a variety of forms, and have found no discrepancy. We say, then, that any form of diagonal can be successfully applied to this system. Having the form of the dead-flat frame in the body-plan, and the diagonal carried as before stated, through the centre of the bilge to the cross-seam, (the direction, however, is not arbitrary,) we may next take the half-breadths from the half-breadth plan of this diagonal line, and whatever distance they fall within each other on this diagonal in the body-plan, a spot may be made; this diagonal line may be taken swung off, or taken horizontal, but as the first half-breadth is taken, so all the remaining ones should be; that is to say, if after we have the line in the body-plan showing its direction, we measure the half-breadth of the dead-flat frame from the point where this line terminates, to the middle-line horizontally. We must also set off in the half-breadth plan this half-breadth, as the starting point for sweeping in the diagonal. It will be necessary that we should divide the half-breadth and sheer-plans into the spaces for the frames, (as this system contemplates the shape, and not the stations of the frames,) and having done so, we next

take off those half-breadths and apply them in the same manner as we took off the dead-flat successively above each other in both body-plans; and although the diagonals in both bodies end at the same point on the middle-line, and are equi-distant on the dead-flat frame from the middle-line, it does not follow that the form of the diagonal in the half-breadth plan is alike in both bodies. We may remark here, that if the settings off on the diagonal are horizontal, the line in the body-plan need extend no farther than the last frame, or the last setting off, but if taken swung off, it should extend to the middle-line. It is presumed that the openings on this diagonal line in the body-plan are to be the largest that can be found on the bottom, and being so, may be regarded as unit or 100. We may now exercise our judgment in arranging diagonals, both above and below this line; this, however, is only a temporary arrangement, until we determine the proportion the diagonal bears, not that it will not apply equally well anywhere, as far as the shape is concerned, but we shall find it much more convenient to calculate; for example, 75 or 80 per cent. than $81\frac{1}{2}$; and this is why we would so arrange the diagonals that an even ratio may be obtained. In Plate 10 we have assumed the ratios to be what they are there shown to be; had

we wanted a different formed ship, we could have obtained it by altering the ratio; that is to say, if we desired to make her sharper below the first diagonal swept in, we have but to call the diagonal showing a ratio of 75 parts to 80, and we increase the spaces between the frames at that diagonal, or cause them to fall in faster; on the other hand, if we wanted to make the ship fuller, we have but to make the 75 parts pass current for 70, and we have our desire; the spaces between the frames in the body-plan growing smaller, it follows that the ship is fuller on that particular line; but again, we may accomplish the same end by changing the location of the diagonal, while its ratio remained the same. Thus we see that a system of proportion is at once established—based upon the proper formation of the greatest transverse section; and if we are so disposed, we may carry the system to the rail, instead of stopping at the load-line of flotation, and perhaps there would scarce be a discrepancy found, in the example given in Plate 10. The most important feature in this system, is its simplicity; it is adapted to the wants of all, and perfectly comprehensible to the least discerning mind. We admit that a small share of experience is requisite to determine the form, but we should be quite unwilling to set prac-

tice aside altogether, and substitute theory in its room; but to the operative mechanic this method of modelling vessels will at once commend itself as being adapted to his wants. It stops not here; it is not enough to say that it will give us a form for the ship, or other vessel, but we may add, that it will regulate any form, without materially altering the shape, unless the shape to which it is applied be distorted by disproportion; it is applicable to any dimension, and tenders its aid as a universal alkahest for many of the marine architectural blunders for which the present age has become notorious.

In reviewing the many and difficult questions involved in an effort to elucidate the philosophical principles involved with the building of ships, we are forcibly led to exclaim with a distinguished writer on Naval Architecture—"To whom are we to look for improvements in the construction of ships? Is it to the men who may bring forward some geometrical or mechanical series of curved lines for a ship's body, deduced from one or more curves? for this has been many times done, and may be performed by the mere dabbler in the art, or to those who, *regardless of any rules*, build ships by what they call the eye! for there are many of these; and when either are asked for reasons for any

particular construction, they assume mysticism, and would appear wise by saying nothing. Certainly from no such men are we to hope for improvements in a science pregnant with difficulties, to surmount which seems to exceed the force of the human understanding."

But let us look for the advancement of Naval Architecture to those who unite the theory with the practice—who are patient observers of the physical facts which experience brings to their view, and have sufficient science to account for these, either by laws, long established, or if not, to endeavor to discover new ones. For what is theory in its legitimate sense but a law or system of laws, established and confirmed by a series of well-conducted experiments? We may, perhaps, be allowed to add, that theory and practice combined constitute *Art*, or with Shakspeare exclaim, that "*Art itself is Nature*," and qualify the former in the language of Pope—"Art is but Nature better understood."

In our expositions of the system we have introduced in this chapter, it will be understood that the diagonals (or angular lines) have no connection with the middle line—the line running through the bilge, which we have valued as 1, or unit, may take its departure from the side-line in the body-

plan, because we cannot determine the form of the entire line in its rotundity without the connection, but after this line is determined in its relative form, the connection may cease; by this method the labors of the loft may be materially abridged, and the work performed with an equal amount of exactness.

In the application of this system to the topsides of the vessel, we may adopt the straight, or sheer-line, and the proportions will apply equally well. We may, however, find it necessary to depart from those proportions above water, particularly on the anterior part, or on the flare of the bow, which beautifies and adorns this part of the structure. When this is the case, it will only be necessary to take the lower sheer-line for unity, and proportion the sheer-lines above in their proper ratios. In applying this method to the loft, we have but to regulate unity in the half-breadth as taken from the draft, and transferring it to unity represented in the angular line in the body-plan. After having swept in the dead-flat frame, we shall be able to sweep in every frame with precision. Supposing any two frames to be a given distance apart on the line marked 100, and we require the distance on the next line above or below the line for example marked 75; and assuming the space on the line

marked 100 to be 10 inches, we now want to know what it should be on the line marked 75. We obtain it in the following manner—

$$\text{If } 100 : 10 : : 75 : 7\frac{1}{2} \text{ or } 75 \times 10 \div 100 = 7\frac{1}{2}$$

inches
inches
inches
inches

The openings may be thus regulated (it matters not how small or how large they may be) with precision. This system of proportions is not however confined exclusively to this arrangement. In all questions assuming an algebraic form, it is absolutely necessary that we should assume proportions upon which we can base our calculations, and from which we may arrive at inevitable results. If we assume the dead-flat frame to be of such form as we desire, and the load water-line to be formed in accordance with our judgment, the remaining parts below are readily determined, and the spots thus obtained will prove the surpassing accuracy of numbers for mechanical operations (when properly handled.) If we assume the body-plan of a ship to be divided between the base and load-line into six equal or unequal parts, as we please, the lines being horizontal and parallel to each other, and the load-line shown in three plans, viz., the sheer, half-breadth, and body-plan; in the former and the latter it will show but a straight line, while in the half-breadth plan it exhibits the form in its rotundity. The load-line being



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... in its rotundity. The load-line being





the widest part of the bottom, we set against it 1000 or unit, which is 1. Suppose, as is the case, the half-breadth of $\otimes$ frame to be 13 feet on the load-line, 12.89 on the fifth water-line, 12.75 on the fourth water-line, 12.46 on the third water-line, 11.58 on the second water-line, and 9.83 on the first water-line; now it will appear quite manifest, that those several breadths are units, or whole parts, this being the widest frame in the ship, and as the lines below grow narrower on all the frames, or have less breadth successively as we descend, it follows that the lower half-breadths of the dead-flat frame are of necessity fractional parts of the unit. We will now give the half-breadths of the dead-flat frame, on the several water-lines, first in feet and inches, then in feet and decimal parts, and third in decimal parts of the unit. First—the load or sixth water-line equals 13 feet; fifth water-line, 12 feet 10 and three quarter inches; the fourth water-line, 12 feet 9 inches; the third water-line, 12 feet 5 and a half inches; the second water-line, 11 feet 7 inches; the first water-line, 9 feet 10 inches. It will be observed that there being no inches appended to the half-breadth of the dead-flat on the load-line, the expression is alike, in both cases 13 feet; the half-breadth on the fifth water-line is 12.89 feet; on the fourth, 12.75

feet; on the third, 12.46 feet; on the second, 11.58 feet; and on the first, 9.83 feet. These half-breadths are respectively represented as follows—the sixth or load-line, unit 1 or 1000, which is the same thing; the fifth is to the sixth as .993 is to 1000. Hence it follows that the half-breadth of dead-flat on the fifth water-line is nine hundred and ninety-three thousandths of that of the load-line, as is recognized by the above expression. So also with the fourth water-line: that is to the load-line as nine hundred and eighty-one is to one thousand, and also expressed as above .981. The third water-line half-breadth is likewise expressed in the same manner—twelve feet five inches and a half equals .958 of thirteen feet. The second water-line half-breadth being eleven feet seven inches, is equivalent to .891 thousandths of thirteen feet, or the half-breadth of the sixth water-line. In like manner the first water-line bears a ratio of .756 thousandths of the load-line, or of thirteen feet.

We have thus given the ratios of the greatest transverse section, from which it follows that the half-breadths of every frame (according to this system) bears the same ratio to its own half-breadth on the load-line, that the dead-flat does. We shall denominate the load of flotation unit, or 1000, on every frame;

and assuming that the greatest transverse section and the load-line are about right, we have the intermediate immersed space to furnish by calculation. Having determined the breadth at the several water-lines on the dead-flat frame, it is necessary that we proceed to obtain the breadths on the several frames, or fourth frames, at the load-line of flotation; and having set down their breadth in feet and inches, or feet and fractional parts, which half-breadths, it will be remembered, are each in themselves a unit, because the several frames are wider, or have their greatest breadth at the load-line of flotation, we have the half-breadth of the dead-flat, which is 13 feet. And we will assume the half-breadth of any frame (say frame 20) to be 8 feet on the load-line; we now want to find the half-breadth of frame 20 on the five water-lines below the load-line; we have already found that the fifth water-line was .993 of the sixth at dead-flat, we then have the following formula to determine the half-breadth of frame 20 on the fifth water-line—As 1000 : 13 feet :: .993 : 12 feet 10 inches three quarters and nearly one sixteenth, or if the extreme breadth on the dead-flat is thirteen feet, what is the half-breadth of frame 20 on the fifth water-line? Supposing that of frame 20 to be 8 feet on the load, or sixth water-line,

we shall be able to determine the entire shape of the bottom in the manner already shown; and to illustrate the principle more fully, we will take another example. It will be remembered that when we supposed the half-breadth of frame 20, we did so because we had not given the proportions, or the actual half-breadths of the load-line on every frame; and we had not given those half-breadths for the obvious reason that it would tend to confuse rather than instruct, to impart a second series of proportions before the first was fairly digested, or properly understood. Hence the reason of adopting the present course; but this cannot alter the results; it makes no difference whether the half-breadth of frame 20 is 8 feet, or any other number of feet, the proportion will hold good with any number.

We will now take an example on the fourth water-line with another frame. Supposing frame 12 to have 9 feet 4 inches for its half-breadth at load-line, required the half-breadth of the same frame on the fourth water-line, we then have but to reduce the 9 feet 4 to inches, also the 13 feet, the half-breadth of ⊙ frame, when we have the formula in the following shape—

$$1000 : 112^{\text{inches}} :: .981 : 108\frac{1}{2}^{\text{inches}}$$

or 9 feet and $\frac{7}{8}$ of an inch. In this latter example, we have found that the

first term remains the same as in the first example, while the second has altered; but it must not be forgotten that the breadth on load-line is a unit on every frame, and this being placed as the first term, must not be otherwise represented. The second term being the actual breadth expressed in feet and inches, or in feet and decimal parts, it follows that the third term will be the ratio the half-breadth of dead-flat frame on load-line bears to the same frame on the water-line, upon which the breadth is to be determined. The last example can also be expressed as follows:

$$1000 : 9.33^{\text{feet}} :: .981 : 9\frac{1}{2}$$

the result is the same.

We will follow those examples through the first series. The half-breadth of another frame on the third water-line will in like manner be determined. We will assume its half-breadth to be 8 feet 7 inches and one-eighth at load-line, and we require the half-breadth at the third water-line; we will for convenience call the frame 14; the half-breadth is expressed thus: 8.59—as we shall find by referring to page 3—we then have,

$$1000 : 8.59^{\text{feet}} :: .958 : 8.12^{\text{feet}}$$

which last or third term is the ratio the dead-flat frame on third water-line bears to the same frame on the load-line; hence it follows that the

proportion gives $\frac{\text{feet}}{8.12}$ nearly, or 8 feet 1 inch and a half nearly. The second water-line on the dead-flat frame is to breadth on load-line as .891 is to one thousand; and if we assume the half-breadth of any frame on that line to be any breadth we please, say 7 feet 9, and we shall again find the same proportionate results: $1000 : 7.75 :: .891 : \frac{\text{feet}}{6.90}$, the result is 6 feet 10 inches and nearly seven-eighths. The first water-line being .756, furnishes all the spots that will be necessary to complete the first series of proportions; and it may be well here to remark, that the calculations, if made with care, will be found to furnish the spots much more exact than any man can determine them by the ordinary mode of taking off tables and fairing on the floor. No man, we care not how careful he may be, can even approximate the accuracy that this system furnishes, and we speak on this wise in reference to all the calculation pertaining to a ship. There are, however, a variety of ways to determine the body of a ship, as we have already shown; and perhaps it would not be out of place to delineate other methods. Before doing so, it may also be necessary to add, that those several modes are applicable to the draft more particularly, and could not be applied directly to the ordinary water-line model, unless the lines of

the bottom were first obtained and applied to the model, for the purpose of projecting the topsides, which method may be worthy of consideration, for two reasons. First, inasmuch as it is very generally conceded that no man's eye can penetrate the mysterious labyrinths of nature, without assistance procured by a knowledge of her laws, as may be inferred from what has been already shown, that the man who models a vessel without this knowledge, would do well to take the draft as a chart, and carry out some one of the systems that we have and will exhibit; and having familiarized his eye with shape on the plane, then make the application in its rotundity on the model, carrying up the topsides to suit his taste, or the peculiarities belonging to the business in which she may be engaged. The second reason is found in the fact, that the diagonal line is not shown on the water-line model, although it approximates nearer to the actual direction of the molecules of the fluid, when propulsion is applied for overcoming inertia; and if the model were made in a manner we have described in Fig. 16, showing the water-line and the diagonal, it would then be almost impossible to make the application on the model direct; to say the least, it would be attended with many difficulties; whereas many who are

not familiar with the draft, would find that time could be saved in making themselves familiar with shape on the plane. Indeed we may not be confined to the manner of determining the proportions from the body-plan, only in the manner we have shown from the diagonals. We may divide the body in the usual manner, at regular intervals, by diagonal lines; not, however, by paying direct reference to the length of the timbers, as is the case on the floor of the mould-loft, but by arranging the lines in such a manner as equalize, or nearly so, the spaces above the first diagonal, both on the middle-line and on the dead-flat frame. We may then, in a manner we have before shown, sweep in the dead-flat frame; and the diagonal running through the bilge (which, as also shown, represents unit) and proportion, those above and below finding the ratio each bears to the first, and marking them respectively according to their value, (those who are at all familiar with per-centage, must readily understand it;) but it does not follow that the line we have denominated unit or 100, should be actually the longest. Assuming the one above were 10 per cent. longer, it would be only necessary to mark the line 110, and we have the ratio; and having this, we may sweep in any diagonal we please; the ratio must regu-

late the shape : after we have the frame and the longitudinal line, we shall be able to obtain a fair and a proportioned bottom. In this manner we may also practice drawing with great advantage, and we shall be able to advance beyond our former conception. It must not, however, be supposed that the draft alone will furnish us with a correct idea of shape in its rotundity ; this would be requiring too much : but with the draft and model united, we may have all that we require. With the model alone, we are dependent upon the eye, and must of necessity be thus dependent, unless we draw the draft, and make moulds from it that can be applied in the manner and at the place at which they were made. This would seem to be the most indirect manner of accomplishing our purpose. It would be more readily accomplished by carrying out the proportions on the draft, and then taking off the water-lines, as shown, or spaced on the model, and from these lines make the model ; or perhaps we should be more definite by describing the process differently. Assuming the body-plan to be already swept in by the diagonal lines, (it matters not for our present purpose whether they are swept in the half-breadth,) we may now divide the body-plan into sections parallel to the base-line, as high as the load-line of flotation ; and on those assumed water-lines take the half-breadths, the same as we would were we laying down a water-line model, or laying down the water-lines, which in fact we would be. In this operation it would be necessary to draw the sheer-plan on the draft, else the ending of the lines could not be obtained. Hence it would be necessary to apply the draft to the model in this particular also, or we could not accomplish our purpose ; and having carried our model as high as the load-line in strict conformity with the draft, we could finish the part above water in unison with the dictates of our experience. It might be found necessary, in order to make the application in the latter case, to transfer the settings-off to the half-breadth plan also. In the mode of proportions by water-lines we may determine even more than the actual formation of lines ; these proportions will furnish the actual displacement of the ship at any line of flotation, after having first determined the actual area and capacity of one section. To illustrate this we will assume the water-lines to be two feet apart, and that a temporary line be drawn longitudinally parallel to load-line in the sheer-plan, or transversely parallel to load-line in the body-plan, one foot down, and half way distant to the water-line below ; let the same be

done with each section, so that the water-lines in the body-plan have between them a temporary water-line equi-distant from each. We will now assume the area of the upper line thus temporarily drawn to be 110 square feet; this multiplied by 2 furnishes the solid contents of the half-section, or of the space contained in the first two feet below the load-line. The ratio of the second section may be 75 parts of the first; we then have a formula like the following—If 100 parts give 220 cubic feet, what will 75 parts give? The result furnishes 165 cubic feet. We may pursue the same course with those below, by first converting the area into cubic feet, and then by the rule of direct proportion we may find the solid contents; and this rule will be found to approximate the former system of proportion by diagonal lines, if we will but mark as before the temporary water-lines and find the proportion one area bears to the other. In this case it is but an approximation near enough, however, for very many purposes for which an approximation only might be required. In determining the body or the capacity of a vessel by this method of proportions, it is important that the question should be stated properly, else we may be subjected to very great errors. Although those problems are but simple sums in the rule of three,

with which every school-boy may be familiar, yet many may not readily know how to test the truth of the statement, or be able to tell positively when the sum is properly stated.

It is a property of proportional numbers derived directly from the definition, that the product of the *first* and *fourth* terms is equal to the product of the second and third. Hence it follows that when three terms of a proportion are given, the fourth can be found. This is the basis of all questions in the rule of three. The foregoing remarks apply exclusively to geometrical proportion, or when the proportion consists in the equality of ratios.

The method of proportioning by water-lines is somewhat objectionable, for two reasons—First, it furnishes a continuation of the bilge to the extremities, in due proportion, it is true, which may seem to be a plausible theory to many, yet it has objectionable features that will be rendered quite apparent to the discerning mind upon due reflection. The bilge, however necessary at the middle of the ship to sustain the leverage of the masts and sails in propelling the ship onward, or to maintain practical stability when without cargo and in a state of rest, must be regarded as detrimental to speed, when viewed as a restorative on

the posterior part of a ship. The sudden and irregular change of course the fluid takes in its passage aft creates a re-action, that serves as a regulating medium; the consequence is, that a portion of the fluid is constantly performing the office of false stern, and serves as a regulator or conductor to convey the contiguous columns to their wonted equilibrium. This property does not contribute to increase the disturbance on the bow, but does very materially increase the resistance on the after end of a ship. The second reason that may be assigned for repudiating the proportional water-line is its tendency to diminish the practical stability. The thinking-man has but to reflect that the greater the buoyancy near or at the extremities of the ship, the less stable the ship. Buoyancy located here to any considerable extent has a very deleterious effect on the stability of vessels, even when the vessel is light, or without cargo. Not so with a distribution of the buoyancy at the bilge near the centre; when light, she covers a broad surface, which sustains her in an upright position, but when buoyancy is concentrated at the end below in an undue proportion, the vessel must of necessity careen or incline easily when light.

We have already shown the effect of having a short floor transversely,

and this quality has the same effect upon the practical stability of vessels that a short floor transversely would have. Proportions by water-lines, however, would equalize the weather and lee-lines of flotation, and furnish a very burdensome vessel. It must be remembered that each water-line and frame would bear an impress of those from which the calculation is made. This is not the case with ratios by diagonals; we may obtain what shape we desire through this channel, and without exceptions we are not trammelled when we start right. If we want a fast or full vessel, we can obtain suitable shape for either, and there appears to be but a single objection to the introduction of this system of modelling vessels, (apart from the controlling influence of prejudice;) this objection is found in the fact that we all want to see the end at the beginning, or to have the whole shape before us from the commencement of our labors. This wish is gratified in the use of the model, and cannot be in the use of the draft, notwithstanding they are, or may be used in connection with each other; but this is not all, there are some who build vessels, and even some who build ships, and are styled ship-builders, who cannot draw a draft. Hence any system, however feasible, that requires the use of the pen, will be repudiated.

There are some problems connected with building ships upon scientific principles, that cannot be determined apart from the draft; and again, on the other hand there are others that require the model for their solution, as we have partially shown, and unless a unison takes place, the progress of this science must of necessity be slow. Experience in this particular enables us to speak confidently, knowing as we do that the discovery of this system of ratios was consequent upon the use of the draft; we practised and taught—First, proportions by water-lines as connected by the ratios from the middle-line, and subsequently discovered that diagonals might be used with still greater success; but to those who will not depart from their dependence upon the eye, we say the model has no equal in delineating shape in its rotundity. But there are still other modes it is said for determining the proper plan for vessels of all descriptions, the most prominent of which we shall notice.

Plate 11 describes the path of the planet we inhabit in its trackless evolutions around the sun. The path as thus delineated is assumed by more than one theorist to be the form, and the only form, that will successfully compete with all others in attaining a high degree of speed. It will not be necessary to reiterate what we have

already stated in relation to resistance; it would seem, however, that very many of those who are so fond of spinning fine theories, know somewhat less than they should about the element they would teach the world to navigate. That inertia forms a great bulk of the actual resistance, no one will deny; but what analogy exists between the resistance encountered by a body propelled through air, and the same body partially immersed in water, and wholly sustained by its buoyant and non-elastic power? We ask this question in all candor, believing that those persons who would embark in an expedition for the attainment of high speed, either in steam or sailing vessels, would do well to look to this distinction in the circumstances of the two bodies thus differently supported—the one by an elastic, the other by a non-elastic fluid. Again, water is composed of round molecules, to perform the office of rollers, which are set in motion on the very smallest application of power, and the vessel moves in the direction that power is applied. We say that the circumstances are so entirely different between two bodies—the one submerged in air, the other partly submerged in both air and water, that nothing tangible can be drawn from the earth's path that will furnish a shape for the posterior part of the vessel intended to

navigate the ocean; the aerial navigator may, but the marine navigator cannot: not because we have said so, but because experience has demonstrated the truth of what we have said. The inertia which forms the great bulk of the resistance to be overcome would forever lock every vessel to its native shore, were it not for this essential difference that exists between the two elements, air and water. The molecules of water are like myriads of metallic balls, polished and frictionless. The number applied is in exact proportion to the weight to be sustained; and as there must of necessity be clashing where so many rollers are set in motion at the same time, (unless the shape be a perfect one,) we may safely conclude this clashing to be friction, in connection with the irregularities in the surface of the vessel, and the fibres that protrude from timber of any and every kind, which also materially impede the progress of vessels. By the clashing of the molecules we mean the many different directions they are required to move, consequent upon the deformities in shape. But there is one fact above all others which theorists seem to lose sight of when marking out a course for practical men. They entirely forget that the pressure is at right angles, and consequently the direction of the molecule must be the

same. Notwithstanding they readily acknowledge this truth, we see them delineating the shape by diagrams of the proper form for the parallels to the line of flotation. Practical knowledge has determined one point in relation to the proper formation of vessels for speed, to which theory must yield; it is, that the current formed by the moving vessel should be as little as possible on the anterior part of the vessel. To accomplish this we require an easy bow, which cannot be obtained without length. This point is conceded on all hands—sage, sire and school-boy will admit this, and the theorist himself will not deny its truth. Let this be set down as an axiom, and what inevitably follows? Why, another truth, equally as clear, that the current should be increased on all and on every portion of the posterior part to the greatest possible extent consistent with nature's law for filling a vacuum in the shortest possible time. Is it not plain, that if we would reduce the minus pressure on the stern of a ship, we must increase the current? and the less time required for a molecule to pass from the greatest transverse section to the rudder, the smaller will be the amount of minus pressure consequent upon the revolutions of that molecule; and farther, if they are required to move a certain distance in a given time, their motion

must be uniform. We would next inquire of the theorist whether the earth's path furnishes the line that is best calculated to accomplish this? and whether the operation would be precisely the same on the posterior part, if a ball were projected in air or water? If the molecules of the water were elastic, like air, would they not be flattened by the compression consequent upon the application of power in forcing a body onward? and if so, would they be as well adapted to filling up the measure of their usefulness on the posterior part? and would not the increase of current on the posterior part rather be calculated to retard than to increase their progress, when thus flattened by the collision? These questions theorists should be able to answer from theory alone, before venturing to define or determine the shape of vessels designed for navigating the ocean. Experiments upon the ocean by practical men have solved those problems beyond question or cavil. We frankly admit that there are many questions yet to be determined, that have not been disposed of by practical men, and perhaps will not be for ages; but we say that the earth's path does not furnish a shape adapted to high speed. Mr. Russell's wave principle approximates much nearer. In Plate 11 we have given an illustration of the form of each end of the line of flotation

in strict conformity to the earth's path, as the theory contemplates the same shape on both ends of the vessel. We have assumed the following dimensions—length 170 feet; breadth 37 feet 4 inches; and applied the half-breadths in the following manner, by dividing them into 128 equal parts on the dead-flat frame. The distance from that point to the bow may be divided into 16 equal parts, at each of which the following would be the half-breadths, commencing at the forward perpendicular, which will be found to require 1 part, and its half-breadth would equal $\frac{\text{feet}}{.07}$. The next would require 4 parts, and would equal $\frac{\text{feet}}{.58}$. The next would call for 9 parts, equal to $\frac{\text{feet}}{1.31}$; 16 parts would be the half-breadth of the next, equal to $\frac{\text{feet}}{2.33}$; the next, 25 = to $\frac{\text{feet}}{3.64}$, 36 follows = $\frac{\text{feet}}{5.25}$, 49 = $\frac{\text{feet}}{7.08}$, 64 = $\frac{\text{feet}}{9.33}$, 79 = $\frac{\text{feet}}{11.52}$, 92 = $\frac{\text{feet}}{13.42}$, 103 = $\frac{\text{feet}}{15.02}$, 112 = $\frac{\text{feet}}{16.33}$, 119 = $\frac{\text{feet}}{17.35}$, 124 = $\frac{\text{feet}}{18.08}$, 127 = $\frac{\text{feet}}{18.52}$, 128 or $\otimes$ = $\frac{\text{feet}}{18.66}$. Thus we have given the half-breadths at each one of the sixteen settings-off.

It is assumed by the projectors of this scheme for modelling vessels, that inasmuch as inertia forms all the resistance that is worthy of notice, it follows that resistance may be measured on any vessel built in accordance with the provisions of this theory; but we have seen nothing in theory or practice to furnish data of the resistance, or





the power required to overcome it. By this system the inertia of the current on the bow, must of necessity be equal to that of the stern—a result not sustained by experience. Much depends upon the application of the propelling power, the leverage, &c. Motion in vessels may be regarded to some extent as analogous to the law of motion in mechanics. An increase of speed is at the expense of power; but the diminution of power is much more rapid on sea than on land.

We have shown on Plate 11 a form much better adapted to the purposes of speed for the after end of a ship than that we have already described; and having had some little experience in forming shape for high speed, we hesitate not to say that the latter-formed line of flotation will allow the water to close up the cavity with more force than the former shape, and not only so, but the equilibrations, which must of necessity take place on the after end, are more rapid. The formation of this line accords with the theory in one particular only. The divisions are made in the same manner, but the proportions are not correct. We have applied whole breadths at the same settings-off that we applied half-breadths in the former case. The proportionate dimensions assumed for the practical application of the theory, are better

or more favorable for its adherents than those in general use. 170 feet on load-line, or between perpendiculars, is seldom connected with a beam of 37 feet 4 inches. Ships (with few exceptions) have a less proportion of beam, which would extend the breach or discrepancy still farther into this theory; or while it would operate more favorable for the bow, it would operate less favorable on the stern. It will require but a moment's reflection to discover, that if the two ends of a vessel are required to be alike in shape for speed, the fluid should be alike circumstanced on the two ends. No one will, we are persuaded, call in question this dogma; and if true, is it not equally true that the fluid is not alike in condition on the two ends? Will any one doubt that the water is more disturbed on the after end, or after having passed the greatest transverse section, than at the forward perpendicular? We think this position is also to be maintained. Then it is equally clear, that if the water is more disturbed on the posterior than on the anterior part, it is also less buoyant, and if there is less buoyancy in the water on the after end, there should be more buoyancy in the vessel; if not, what is the result? why, at high speed the vessel settles by the stern, and draws more water aft than when at rest. Here we see that

universal law of motion carried out fully. An increase of speed is at the expense of power, and this is true both with regard to the vessel and the water. As the water becomes less buoyant, its current must be increased, in order that we may maintain the same amount of buoyancy; and although about the same amount of resistance is encountered by the application of an equal amount of power, yet the speed is the regulator; and were we to admit that the same amount of power applied on two vessels would create an equal amount of resistance on the bow, it would not follow that the speed would be alike in both vessels; and the vessel that had attained the greatest speed might have had the fullest bow and the best after end for restoring the water to its former equilibrated state. Many men of experience, and even ship-builders, think that it cannot be, that we are familiar with the results of experience in this country, else we would not advocate the full after end. It is for this very reason that we are found where we are on this, as on many other points connected with building ships. If our ships are required to sail no faster than they did thirty years ago, then we say the fore end the fullest, or the full bow and the lean after end; but if our freighting ships are expected to sail faster, and at the same time

carry as much or more, they must have a different shape; and if we would maintain our supremacy in this particular, we must adopt such measures as will secure those advantages to ourselves that nature has placed within our reach. Talk about the full after end to a ship for speed, and the ship-builder stands aghast; his thirty years' experience repudiates the idea; the captain cries out, "preposterous! she won't steer:" this is the watch-word that is passed along, and finds a response throughout the ship-yard and throughout the ship. From those two channels emanate what may emphatically be termed the *inertia* of public opinion with regard to the proper formation of vessels. How essential then it is that our ship-builders and ship-masters should be scientific as well as practical men. We cordially agree that their views are correct as to the shape for moderate speed; but let it be remembered, that the commercial world are not content at moving at the same pace they did some thirty years ago. 9 knots by the wind will not do for the middle of the nineteenth century. Neither will the same shape answer for high speed that we have made for a more moderate speed. We mean the same proportions in shape; that is to say, if 20 per cent. of buoyancy is taken off the fore-body to in-

crease the speed, it does not follow that 20 per cent. of the buoyancy should also be removed from the after body. Many, however, are ignorant of what kind of fullness we mean, when we say that for high speed vessels should be fuller aft. It is well known by many ship-builders, that on many of our sharp vessels the water rushes to the surface from below before it reaches the rudder. The consequence is, that the vessel settles; she is not sustained long enough. If the vessel was so formed below as to conduct the retiring columns farther aft, she would not settle; the water would be conducted with more force to the rudder, which, so far from making her steer worse, would cause her to steer much better—so much so, that in many cases one-half of the rudder would accomplish all we could desire; for it is plain even to a prejudiced mind, that when a vessel is very sensitive at the helm, she has too much rudder; but this advantage would be seen and felt more particularly in scudding, when the rudders of most vessels seem at times to be powerless. This tendency to settle aft in vessels as now found, when forced to a speed beyond that to which they are adapted, is rarely seen, for this reason—sailing vessels are more or less, under all circumstances, affected in their trim by the leverage which conceals this tendency

by counteracting it, and causing them to set by the head; and we have known reputed fast sailers of the old form to be 3 feet by the head when under a press of sail; whereas the same ship when relieved from the leverage of sail, would be 1 foot by the stern. Hence we say this discrepancy is rarely discovered; but under some circumstances it is to be seen when the effect of the leverage is directly abeam, and the ship is fully up to her speed. In steam-vessels it is often seen, although the shaft is high above the centre of buoyancy, which (unless the discrepancy were of some magnitude) would tend to elevate the stern and depress the bow.

In endeavoring to unfold the discrepancies of one of the most plausible theories yet advanced for the formation of vessels; and in showing the extent of this *inertia* of public opinion in this branch of mechanical skill, we are not disposed to take aught from the well-earned reputation of American ship-builders, who have done much to improve the complexion of American commerce; but we do say, that were scientific knowledge as universally diffused among them as it should be, ship-building would no longer be regarded as a dark, mysterious, and half-developed system, but as the most brilliant, harmonious, and beautiful of all sys-

tems, rising like new *Cythera* from the enchanted wave. We should not so often hear the direful tidings that are now wafted on almost every breeze, of the wreck of that surge-beaten bark having been swallowed up amid the mountain-crested billows of that dark abyss ! that heart-rending news would not so often break upon our ear, that our friend or kindred has found a winding-sheet beneath that dark blue wave. The silent foot-fall of time has thrust us across the threshold of an era in which the car of lightning mounts its frictionless wheels, and is spurred onward by commercial enterprise. Every other subject within the grasp of thought has contributed its quota toward the onward progress of commercial science but that of ship-building.

The pages of this chapter have been thus far devoted entirely to shape ; we deem it necessary to follow other theories of the present time, inasmuch as it will doubtless be admitted that there can be no progress without a knowledge of the past, it is equally apparent that we must know all that is worth knowing of the present.

From the days of Archimedes to the present there never has been a time when the world was not indebted to some zealous adventurer in this branch of commercial science. Many, however, have lived and died with no wider

extension of their fame than the orbit of a few leagues from the spot that gave them birth ; and from the palmiest days of the Syracusan philosopher to the middle of the nineteenth century, not one single theorist has accomplished anything worthy of the name, without practical knowledge. In more modern times, we have an illustration given by Colonel Mark Beaufoy, in a series of experiments from the year 1793 to 1798, upon the solid of least resistance ; the results of which have been of no value to the science of building ships ; and although the amount of labor attendant or consequent on such a series of experiments can scarcely be conceived, yet a more uninteresting scientific work of near 700 pages, was perhaps never published in the English language, having not the most remote connection with that branch of commercial science which exhibits either natural or mechanical philosophy in building ships. In those experiments the solids have scarcely the least analogy to the form of vessels, and were submerged six feet beneath the surface of the water ; but however destitute this volume may be of practical utility, there is another of much smaller dimensions that seems to demand a passing notice ; not that we consider ourselves in the light of reviewers of works upon the science of

ship-building, but because we have undertaken to connect science with practice in building ships, and as a consequence find it very essential to know what has been done before we can determine what may be done; and it would have been well if the letter to the author, found on page 93, could have been published centuries ago; doubtless many would have been dissuaded from wasting time, talent, and money, in fruitless efforts to set the world aright by beginning at the wrong end, by substituting theory for practice.

We should have been content to have ended this chapter without entering upon an analysis of the most prominent features of a patent ship, a model of which was exhibited in London in 1849, by Captain Zerman, a naval officer of thirty-six years' experience. On examining the details of this patent ship, we were involuntarily led to exclaim—if knowledge were commensurate with experience, and experience with age, the present generation would be wise indeed! It cannot be regarded as a digression from the legitimate subjects set apart for this chapter to follow Captain Zerman through the mysterious labyrinth of inconsistencies with which the pamphlet explaining the principles and setting forth the advantages of this patent ship abounds, and shall notice such parts as more particu-

larly pertain to shape. The Captain inducts his readers into the merits of this new system of building ships, that has cost him twenty years' labor, by pointing to the rapid and gigantic strides made in the science of astronomy, and its application to nautical purposes, aided by the discovery of the mariner's compass, and the iron sinews of the steam-engine for the purposes of propulsion. In fact man may almost be said to have overcome wind and tide in traversing the deep; but with all these improvements in navigation and propulsion, there are still *overwhelming dangers, numberless evils and inconsistencies* to which all vessels are exposed and subjected; the truth of which he tells us is sadly illustrated by the shipwrecks which are so frequent. Indeed, Captain Zerman himself refuses to enter into a detailed description of the evils and dangers which surround the mariner on the sea, consequent upon the manner in which vessels are and have been constructed, from the earliest dawns of civilized life down to the perfection of modern times; they, by Captain Zerman's history, have been constructed upon the same fundamental principle, the basis of which has been a *keel*. From time immemorial the *keel* has been deemed as necessary for a ship, as a spine for the human frame; but

the author of this stupendous (*mis*-) improvement in building ships, tells the commercial world that the *keel* is the great source of most, if not all, the evils attending the navigation of the seas. But we will allow this inventor to speak for himself. Says he, it is obvious that a ship constructed with a keel takes an enormous draught proportionately to her tonnage; and notwithstanding her depth of keel, she has no natural or intrinsic stability, since she cannot go out of the harbor without either ballast or a proper cargo. This ballast gives her an artificial or extrinsic stability, and from these two defects (enormous draught and extrinsic stability) naturally and inevitably follow all the evils, difficulties, and dangers of the present system of ship-building and navigation. He then proceeds to furnish the catalogue: the continual rolling and pitching, which shakes the whole frame, and tends to weaken it, and in continuous storms causes leakage, which may tend to loss; the drifting of the ship with head winds, when she can only advance by tacking or veering, which renders her voyage much longer, and is sometimes driven ashore, or upon rocks; the necessity of deep water for ships of large, and even for those of small tonnage, which increases the danger, and prevents her from navigating numberless rivers; creates

additional expenses in loading and unloading; entails the necessity of taking in ballast and throwing it away, which incurs a great loss of time and money, and is often attended with the greatest difficulty; which ballast, moreover, is unproductive dead-weight, and diminishes the capacity for cargo; increases the bulk of water to be displaced, and as a consequence the resistance to be overcome; and to the above may be added the difficulty of manœuvre, the short average durability of the ship, cost of construction, the high rate of insurance, which is proportionate to the risks and dangers of navigation. Since, then, (the Captain adds,) the *keel* is the source of so many of the dangers a ship has to encounter on her voyage through the seas, how is it that no one has ever thought of preventing the effects by removing the cause? Thus we discover the result of theory without practical knowledge. The author of this discovery after twenty year's labor in endeavoring to overcome the many *almost* insurmountable difficulties, has discovered that if one *keel* is the cause of so many disasters, that two *keels* would remove the difficulty entirely. We remember never to have read of any scheme for navigating the *air*, much less the ocean, so completely baseless as this: and did not the patent and description

bear date of 1849, we certainly should not have given the present or the two last centuries credit for this discovery. The Captain carefully avoids proportions, like most theorists; they allow the builder the privilege of doing that which they cannot do. If theory can describe the form, why cannot theory furnish the dimensions? Had the Captain furnished his own dimensions, he would have exploded his own theory; for it must be apparent to the least discerning mind, that if any vessel were cut into two parts longitudinally through the centre of the keel, and those parts separated a proportionate distance, and planked up vertically as high as the load-line of flotation, and then both parts united above as one vessel, we say it must be apparent, that were the ship in one part as wide as she is designed to be in two, she would perform very differently. But will any mechanic believe that the ship without the keel would draw less water in two parts, more particularly after the weight of bulk-heads and the bracings and necessary appendages for strength have been added? In a word, can a heavy ship displace less water than one less heavy? But we are told that the double vessel would have the bottoms perfectly flat; and may we not inquire if many of our finest ships have but little rise to the floor, and some none

at all? But we are told that the rolling and pitching causes leakage, and tends to weaken the vessel. To this we reply, that the rolling and pitching would affect a vessel in two parts much more than in one, because the ship would roll and pitch much less were she of the same dimensions as another divided. All things else being equal, (we mean with the inboard side of each section perfectly straight,) with regard to ballast, we find no difficulty in this particular in a single ship, if they have beam enough. No freighting vessel need carry ballast if she has a proportionate amount of beam, unless she is freighting unpressed cotton, or very light goods; but how the vessel becomes more capacious by cutting a groove through the centre, and letting the water take the place of what would otherwise be vessel, we cannot tell; nor do we believe the Captain himself would undertake the task: he only tells us that it is so, and leaves us to guess how. But again, we are at a loss to know how the resistance is to be diminished; with all the resistance of the two sides, and added to this that of those vertical parallel planes on the inboard sides, we should say, if called upon for an opinion, that the resistance would be increased at least one-third, inasmuch as the resistance on planes is absolute as well as lateral. That a

ship would very materially lessen the lee-way in the aggregate, constructed in this manner, we are unwilling to admit, notwithstanding a plane is presented the entire length of the vessel, and the full extent of the draught of water in depth. Her increased resistance, in connection with her sluggish movements when in stays, would, without doubt, more than counterbalance any thing gained by the increased lateral resistance. There are two other points to which the Captain has also called the attention of the commercial world, the first of which is the great durability of such vessels; but having made the announcement, he leaves us to determine in what particulars the great durability consists, not being careful to enlighten the world upon this point; and if left to determine for ourselves, we unhesitatingly should decide that vessels thus constructed would not be even as durable as under the present system. But the last particular is that of avoiding many dangers—they are, however, not specified; and we are again left to feel our way without a light. That such constructed vessels would not be liable to more of the numerous evils consequent upon navigating the ocean, few persons qualified for deciding we are persuaded would readily assent. This mode of construction is decidedly more objectionable

than the double boat formerly used on our ferries, but long since repudiated, although the construction consisted of two entire bottoms, but this method is but two half-bottoms, for the reasons already named.

It has been almost invariably the case, that when persons introduce new systems of construction for ships, they are content with exhibiting all the prominent parts of the contemplated improvements, but the details of construction are often left discretionary with the builders. Just so with Captain Zerman's patent ship; he never followed up the consequences in detail of such manner of construction, and leaves the constructor to perfect his outline or design. The world is left to guess their way in more than one particular. That there should be a cavity where the keel is at present, they are made fully aware; and of its advantages they are not kept in ignorance. But the reader must come to the sage conclusion from the captain's own version, that no sophistry can make that right which common sense pronounces wrong; and that less than half of the thirty-six years of the Captain's experience spent in private maritime enterprise, would have taught him the futility of his projected design. Few men have been successful in improving the form of vessels, except those who

have become familiar with all the details of practice. As it has been well-observed, the man is but poorly qualified to judge of models who cannot make one, and the same may be said of the draft. Hence the importance of becoming familiar with the ground-work of science before embarking on its boisterous tide.

The system we have contemplated in this chapter under the head of proportions comes as a regulator ; it does not arbitrarily demand one form for all vessels, nor yet the abandonment of the fundamental principles of construction. With regard to shape, we say the particular object or trade for which the vessel is designed should, to some ex-

tent, determine this ; and with reference to the location and form of the greatest transverse section, in addition to what we have already advanced upon this subject, we will only add, that the speed must regulate its location, and to some extent its form. If we desire to attain the highest speed attainable, whether by the power of wind or steam, the greatest transverse section should be aft of the centre of length on the load-line, in which case the bow should be relieved of the top hamper as much as possible ; the leverage should be regulated to correspond, else the change would prove detrimental rather than advantageous.

CHAPTER VII.

The Author's Discovery in obtaining the Centre of Expansion—Its importance to a Proper Distribution of the materials for strength—Continued expositions on the floor.

In the old world it has been the practice to expand vessels from a base-line assumed to be straight, and from which all the exterior plans would be projected. The entire exterior surface was not only projected, but the form and length of the plank were also shown in their proper places and appropriate lengths; and it is supposed to be fairly assumed, that the proper shape as well as length was actually shown on this plan of expansion, and referred to in planking for the length and sometimes for the shape of the plank. This practice in the United States has been confined chiefly if not exclusively to the several Navy Yards, where a board prepared for the purpose would exhibit only the arrangement of the butts of the plank on the outside of the ship. The practice of exhibiting the shape or *sni* having grown obsolete to some extent, in consequence of the many failures to exhibit the actual form of the vessel in her expanded or extended position, the mechanic, whose business it is to line the plank to its pro-

per shape, assumed that the expansion plan furnished the actual shape; and as a consequence would select his plank in accordance with the amount of *sni* furnished by the expansion plan; and after having been chagrined time after time by this deceptive map of the expanded vessel, the plan at length has been very generally abandoned in this country at least; of its usefulness, however, there can be but little question, if properly and reliably made.

It will appear quite apparent to the discerning mechanic, that could the ship be flattened out to a perfect plane, it would not furnish a straight base-line. Let us suppose the model showing half the vessel in miniature were placed on a plane with the middle-line next to the plane; and for our present purpose the model may be assumed to be made of some material that may readily be brought to a flat surface by the application of pressure; when thus flattened out, we may see the actual form of all and every plank on the exterior part of the ship. This is vastly

important to the young mechanic, inasmuch as he may aspire to the position of leader in this part of the construction of the ship, and should have his eye familiarized with the actual shape of the plank, or the shape required before he can line it to its proper form. The time was when it was supposed to be impossible to line a plank by the eye, particularly the fore and after woods. It was deemed actually necessary to take a spiling from the bow or stern to obtain the proper shape; but in the order of improvements that day has passed, and the practice has grown obsolete. Mechanics no longer think of taking a spiling for a plank, unless in some very peculiar part of the ship, where there may be a poor chance of working it to its berth, and only under some such circumstances is the practice adhered to of spiling for any plank on a ship, the garboard, fore and after woods excepted.

To give in addition to the actual shape of the plank, the proper shift of butts in planking, and of their distribution in the frame, or of the timber of which the frame is composed, may perhaps be thought superfluous by some, but as it pertains to the systematical construction of this stupendous fabric, we think the time well spent by the young mechanic in endeavoring to become familiar with the means of cal-

culating every particular, relative to the quantity of strength, or its proper distribution, as well as to the form of the ship. The utility of this knowledge upon mature reflection we think will not be questioned. With respect to the frame of a ship, it must be apparent that a good degree of skill is necessary to the proper disposition of the timber of which the frame is composed; the variety of curves; the different lengths; the diminished scantling at the extremities, as well as at the rail; all contribute to make the subject one of importance and of interest to the mechanic. This subject has never been made sufficiently clear to the minds of the young and inexperienced; hence the necessity of pausing to inquire what has been done in order that we may know what may be done. The strength of our vessels is a subject worthy of our notice, more particularly when it may be obtained without additional cost. It will not be necessary to enlarge on their importance.

It has been the custom to determine the scantling and arrange the butts of the frame, or the number of timbers composing the frame of a ship or other vessel, upon the floor of the loft. The dead-flat frame being the one usually selected for this purpose, a batten being bent to the shape of the frame, and the size of the scantling set off toward

the centre at the head of the frame, and likewise the size at the side of the keel, a batten is then bent with those boundaries at the head and keel, the intermediate space being determined by the builder. But we apprehend this to be a loose and indefinite mode of determining the size of the frame—by the scantling size we mean the moulding size of the frame from the keel to the head of the frames. The dimensions at the keel, or the depth on the keel, should in all cases be something more than the siding of the keel. In steamships the difference should be greater than in sailing ships, on account of the application of power in opposite directions; that is to say, if the keel of a steamship were sided 18 inches, the depth of the floors should not be less than 20 inches; whereas the keel of a sailing ship, requiring a siding size of 16 inches, should have a depth of 17 to 17½ inches in the throats of the floors, or the depth on the top of the keel. These proportions will apply to smaller vessels, and may be considered sufficiently heavy, unless the vessel be a centre-board vessel, in which case the proportion will not apply. Where light draught of water is of great consequence in smaller vessels than ships and brigs, we may perhaps be quite safe in reducing the size somewhat below the proportion given.

There is still another exception to this general rule when we determine to cover the vessel with plank of more than usual thickness. We may in such cases be safe in departing from those proportions; the usual proportion for the head of the frame, or at the plank-sheer, and one which we should ourselves adopt, would be one-third of the size at the keel; and if the vessel be an ocean steam-vessel, a smaller ratio may be adopted, on account of the extra size at the keel. Our reasons for reducing the scantling when the thickness of the plank is increased, are, that the strength of the vessel is increased faster by increasing the thickness of the plank inside and out, or inside only, than by adding to the scantling of the frame; and one of two methods of reducing the frame may and should be adopted when we determine to add materially to the thickness of the plank, either to spread the frames farther apart, or reduce the scantling size. It may be supposed that a reduction of the siding size of the frame would have the same effect, which to some extent is true; the weight would be reduced, which is a secondary consideration when strength is to be gained. By reducing the siding size of the frame, we bring the fastening closer together than it should be; besides this, there are more grains of the timber cut off with

an equal amount of fastening than would have been with a smaller scantling; consequently more of the strength of the timber is lost, and it also follows that less remains. To make this part more clear, suppose the top timber for example to be sided 10 inches, and moulded 9 inches at a certain place, we bore an inch auger hole through it thwartships, is it not clear that one-tenth of the strength is gone? whereas had the scantling size been 8 and the siding size 11 inches, we shall discover that we should have had more strength left, although the hole for the fastening was the same in size. In the first example we had 10×9 inches, which gave us 90 square inches of transverse area, and it would require 10 of the 1 inch holes to cut off the timber, while in the second example we have 11×8 , which gives 2 square inches less area, and yet it requires 11 holes of the same size as before to cut the timber off. Thus it may fairly be assumed that upon this score alone it is decidedly preferable to have more siding size and less scantling size. But there is another reason why we prefer more size in the siding and less in the scantling—the thicker the planks are, the more longitudinal strength we obtain, inasmuch as an inch added to the thickness of the inside plank, or to the outside plank, is almost equal to sheathing

a vessel, which it is readily conceded is a great addition to the strength; the extra thickness, however, in the outside plank, is the most advantageous on account of the caulking, which by increasing the surface of oakum in the seams, renders the increased thickness of somewhat more service. But again, we would make a still greater reduction in the scantling size, and also reduce the siding size of the lower futtocks at the ends of the ship; this is rendered necessary, it will be at once perceived, for two reasons: first, we shall have much more timber than in other parts of the ship—a difficulty which, without this precaution, we cannot avoid, inasmuch as the contraction consequent upon the shape of the ends of the vessel leaves less room for the distribution of timber below, while above we have more room than we require; and if the siding size of the timber in the futtocks of the cants were to remain as in other parts of the ship, with but a single timber below, both forward and aft, it would be a much better arrangement than at present, and our ships would be stronger and last much longer than they now do at those parts, particularly those built of white oak at the extremities. But there is still another feature to this question that has not been shown; there are two timbers in each frame that ex-

tend from the keel to the head of the frame, with joints or butts at regular intervals. It must be quite clear, that at those butts the frame has but a single timber as it regards strength; that is to say, one timber of the frame being cut off here, the frame is only equal to the strength of a single timber; hence the importance of having as few of those weak parts to the frame, and of keeping those places as far apart as possible, longitudinally as well as vertically. But it may have been supposed, that although the in and out fastening would seem to call for a reduced scantling, and an increased siding size to the frame, yet when the frame-bolts are brought into the account, the advantages would not seem to be so great. To this question we apply the same answer as to the former, viz.: the increased thickness of the plank will more than make up the deficiency; but we have told our readers that the ship would be stronger with less timber: this, although seemingly paradoxical, is nevertheless true. It is a truism that is at once recognized by every mechanic—that to increase the bulk of materials beyond what is necessary to increase the strength, rather weakens the ship than otherwise, inasmuch as the increased strength operates against the weaker parts, and causes those parts to yield more than

they otherwise would yield; besides this, it must be quite apparent that the ends are the strongest parts of the vessel. Under any circumstances, when the usual mode of construction is adopted, the deadwoods are a source of great strength to the part of the ship in which they are located. It will also be remembered, that the proportionate amount of cargo is small that the ends will contain, when this increased strength is considered; and again, that the leverage of the masts and rigging are not even proportionately sustained here, so that we need have no fears in relation to the strength of the ends; and still another reason exists for diminishing the scantling at the ends of the vessel—the plank is usually diminished in thickness at the ends of the ship, and if it is not, it should be, inasmuch as an equal thickness of plank with that of other parts of the ship, cuts too deep a rabbet, which exposes the fastening in the stem and stern-post, or makes it necessary to place all the fastening in the centre of the stem and post, which does not add strength in proportion to the number of bolts contained, unless properly distributed; and it should be an invariable practice to make the rabbet of less depth on the stem and stern-post and dead-woods than on the keel; not because the keel does not require as much support for

the floors and spread for the fastening as the stem and post, but because the rabbet on the keel cuts but little compared with the ends. On the keel, particularly along midships, the angle of dead-rise (on freighting ships particularly) differs but little from that of square with the side of the keel, or of right angles; consequently to make a square seam, we require but the difference between the angle of rise and square, or of right angles, in the thickness of the plank as the depth of the rabbet; but on the stem and post the case is quite different: the rabbet cuts more transversely, and consequently deeper, leaving less wood between the two rabbets transversely; hence the importance of reducing the rabbets on the ends of the vessel; and on sharp vessels it is also necessary to increase the siding size of the keel, in consequence of the increased depth of the rabbet; the siding size of the keel should be with the builder a matter that his own judgment or experience should determine. It cannot be supposed that every matter of this nature is determinable by rule; as no proportion of the dimensions of the ship would be safe to adhere to as a standard.

We have said that the scantling should be smaller, and the rabbets less deep at the ends, because they were the strongest parts of the ship; but

the plank at the ends should also be thinner; they should be diminished at the end to the thickness shown by the depth of the rabbet, and tapered as far from the end as is required to make the thickness a fair taper.

Having shown the relative proportion that should exist between the head and heel of the frames, or the scantling size at those points, and also thrown the builder upon his resources in relation to the siding size of the keel, (not however without first telling him that the depth should be considered as having some relative connection with the siding size,) and believing that we do him a service by thus leaving the matter with him, seeing there are a variety of circumstances that would require a departure from any proportions that might be given, we next come to the manner of determining the size between the head and heel of the frame, or the scantling between those points.

It has been a practice in some parts of Europe to sweep in the dead-flat frame upon the floor of the loft, and strike up the middle-line in the body-plan, from which the scantling size at the head is set off at its proper height, as shown in Plate 12. The size being also set off below, a line is stricken on the floor from spot to spot, and the space between those lines shows the

scantling size of the frame, and is obtained as follows: the middle-line is divided into a convenient number of spaces, and the $\odot$ frame is likewise divided into a like number of equal parts, and lines being drawn from one to the other, or from the middle-line at the upper spot to the frame on the upper spot, furnishes the place where the size is to be taken at the middle-line and applied to the frame. This method is adopted in the United States when any method is adhered to, which is not always the case. We may, by the adoption of this mode, regulate the scantling size as we please, with this exception: it does not provide for a reduction at the extremities, which is its most objectionable feature; that however may be remedied by making the diagonal lines curved instead of straight lines, as shown by the dotted line in Plate 12, which may be so arranged as not to affect the square body, and apply only to the cants. If we require a larger scantling size between the head and heel, we may drop the inboard end of the diagonal, or we may extend the diminishing line higher, and again divide the length on the middle-line, keeping the head and heel the same as before. After having determined the scantling size, the lines may remain on the floor, and the sizes may be marked to correspond with

dead-flat mould on all the other or the remaining moulds in the same body at the place where the diagonal crosses the moulding or outer edge of the mould. The diagonals need not interfere with others that may be on the floor for bevelling spots, if it is thought that they are likely to; they may be marked with pencil to distinguish them, as the diagonals for the bevels and for arranging the butts are usually shown with white chalk.

Having shown the appropriate method of arranging the size of the material for strength longitudinally, and in part diagonally, we may find it to our advantage to inquire what can be done to strengthen the ship's frame, and, as a consequence, the whole fabric vertically. We have already shown that the ship is but single-timbered in the direction of the diagonals, and by which the length of the timbers are determined, while from that point to the next butt, the ship is double-timbered; and this arrangement is continued throughout the entire ship. Thus it is plain that at regular intervals there are weaker places than those above or immediately below. Various measures have been adopted, both in the old and new world, to remedy this manifest defect; but thus far the projectors have only partially accomplished their purpose. A great variety of expedi



ents have been adopted in Europe, none of which have found favor in universally obviating this manifest defect in the present system.

It will require but a glance at this subject by the thinking-man to enable him to discover that the plank runs nearly in the direction of the diagonals outside and often inside of the ship; hence it must be equally apparent, that at every range of butts the strength of the ship is less than it might be with the same material, were it but every third or fourth frame that displayed a range of butts: in the same direction and at the same place that a seam in the outside and inside plank is shown, it would be deemed of less consequence, but this range of butts is found on every frame at the same place. It is true that measures are sometimes adopted to bring the butts of the topsides under the hanging knee, or in a position in which they are supported by other means than that furnished by the plank; but below the decks and hanging knees there is no extrinsic support beyond what is furnished by the bilge strakes, which are, as they should always be, the thickest planks in the ship, because the bilge is the weakest part of the ship, and cannot (without extra means are adopted) be as strong as other parts of the structure; and we have not unfrequently

seen a range of butts at the upper edge of the bilge strakes of a ship, or at the upper edge of the water-ways between decks and at the ends of the hanging knees, which has a tendency to weaken the ship; hence the truth of what we have already said in substance, that something more than the materials are requisite to the formation of a strong ship. This is one of the principal reasons why ships often work at sea, but do not show it when in port. Those butts and seams all in vertical range, and running in the same direction, operate like hinges on a door; the ship may go and come in this manner for a length of time, until she happens to be grounded on the beach, and then the story is soon told. If a ship-owner should think the picture too highly colored, let him adopt a course we shall propose on a ship that has a range of butts in the frame of his ship, at or near the upper edge of the lower deck water-ways. He may think her a strong ship, but let him put in a set of standing knees between decks, load his ship and send her to sea, and more than likely the first gale of wind will break half of those knees, and it is very reasonable that it should. The ship is made very strong above and below this weak part, and the strain of the masts and rigging operate in direct line from the channels through the lower deck

partners to the bilge, and, as a consequence, on any and every weak part between those points.

It may not seem quite clear to all that the bilge should be denominated the weakest part of the frame. In reply to the inquiry why? we would say, that any and every structure can be made stronger with the same amount of materials in the form of a plane, than when the frame or structure has no determinate form; not only so, but the side of a ship is strengthened by the decks very much. This support the bilge cannot have; but again, the bilge has not only the strain consequent upon its own weight, and the pressure within of cargo, and without of water, which are seldom well balanced, but in addition to this, it has the variable strain of both the side and bottom at the same time to withstand, from which we may reasonably infer that we are not far from the truth when we say that the bilge of a ship, having the butts of the frame arranged as they usually are, is not as strong as other parts of the ship by from 10 to 20 per cent. The harder the bilge, the weaker it is, and the reverse is equally true.

We readily admit that many builders do not confine their butts to the diagonals, or do not cut off the timbers by the diagonal lines; but while we admit this fact, we must also state the

reason, which is simply because it is not to their interest to do so. If a futtock will work a few inches longer than the sirmark, the moulder would of course save it on the best timber, whether it were head or heel; whereas it is well known both to the moulder and the framer that it will not do to depart a great distance from the place for the butt, (unless two timbers can be obtained in one,) if they do, the scarf is made too short, either above or below: thus it is plain that in the main the departure is only the exception, and not the rule. But the bilge of a ship seldom receives this advantage; the timber being crooked, is hard to find, and, as a consequence, a butt is made in the hardest part of the crook: this of course relieves the moulder, but diminishes the strength of the bilge.

The casual observer cannot, we think, but admit, that inasmuch as the bilge is the connecting link between the vertical and the horizontal plane, that it requires a greater degree of strength than other parts of the ship, whereas it has less. A variety of means have been proposed, some of which have been adopted, but up to the present time nothing has been presented that will so effectually remedy the evil, as that of an equalized gradation of the butts throughout the ship, and increasing the siding size of the timbers of

the bilge; but even with this additional strength the bilge strakes should be heavier than other parts of the ceiling.

It must appear evident, that a proper gradation of butts can only be obtained from the expansion plan, and the question at once arises, how shall this be obtained, inasmuch as every Naval Architect has thus far failed in obtaining the actual shape of the vessel in her expanded state? Although more than a single effort has been made, the reason, and doubtless the only reason, why European Architects have failed to accomplish their purpose, is attributable to their ignorance of the model. It is this alone that can furnish two curves in the same line, and exhibit both at the same time.

It will appear obvious, that an expanded ship, bounded by a curved line both below and above, must have a straight line somewhere, and that this straight line would be the proper starting point wherever found; as all parts would commence expanding from this line, it is also evident that this line is precisely the same one way when expanded that it was when in its rotundity; hence we infer that it will furnish correct data for the extension of all parts. We have shown the line in Plate 2 in the sheer-plan, and in one section of the half-breadth plan, and it may be obtained

in the following manner from the model: plane up two battens thin enough to bend around the model longitudinally anywhere, and as wide as a good rule-staff should be by the scale upon which the model is made, say 8 or 10 inches; both edges being perfectly straight, apply one around the model at the upper part of the bilge in the direction a diagonal line usually runs; apply it fair, without an inclination either up or down; having secured it, apply the second with its lower edge at the upper edge of the first, as near as may be without its coaking off from the bottom, or having any set edgewise; they may not seam at their first position, as indeed it is not likely that they will. We shall be able, however, to determine in which direction they are required to move, in order to secure a seam or a joint of the two edges; by thus moving them we shall find a position in which they will form a joint of their edges, and at the same time fit the bottom or side of the model; when that plane is found, we have the base of the expansion plan, viz., a straight line. It is true, that all Architects expand from a straight line; but they take it for granted, that because the base is a straight line in its rotundity, it must of necessity be on a plane. We find the straight base, and from its proper location, project the design;

hence the difference lies just here—they place the base at the edge of the design, we near the centre. Having marked the upper edge of the lower staff, or the lower edge of the upper one, we may mark the exact station of every frame on the edge of the staff, (their stations having previously been marked across the outside of the model.) In applying those stations to the draft, it will be discovered, that the dead-flat frame must be squared from the straight line, inasmuch as every other will vary more or less from square as the frame is more or less distant from this frame. We may now girt the $\otimes$ frame in the body-plan, by applying a batten, and marking every water-line below and above; also the sheer-lines. The rail being the upper boundary, and the base or side-line the lower boundary line, the girt of every fourth frame may be obtained in the same manner; the spots should be marked parallel to the base of expansion, for the following reasons: when we have spotted all the lines on every fourth frame, we may apply a batten to each water and sheer-line in the half-breadth plan, marking the station of all the fourth frames on the batten while thus bent; we may then apply the batten to the expansion plan, keeping the dead-flat spot on the batten at the line representing that frame. All the marks on the batten

may now be brought to intersect the girth spots, and the crossing will be the correct spot for the expanded line on the frame it represents. The expanded shape of every line may be obtained in the same manner; and all the frames may also be marked, and will be required to complete the plan. The endings of every line will also be necessary, and may be swept by the spots at both ends of the plan. We shall find that the ends aft form a curious line; and in order to complete the plan, we may find it necessary to run in one or more lines in the buttock after the lines are all swept in, the sheer-lines with ink (and all the water-lines with pencil which are not required) after the frames are regulated and swept in with ink also. We may remove the water-lines with India rubber, and proceed first to the arrangement of the butts of the frame, having the whole side of the ship before us—the lower edge of the draft being the side of the keel, and its upper edge the rail. It may now be plainly discovered that the floors should be the starting point, and that if we determine the length of the floor to be invariable, we return to the present system; but suppose we determine to have 5 feet scarf to the frame, or 5 feet from one butt on the frame to the next above or below, and that every fifth frame shall be the

usual length, or say midships 10 feet, arm and cut by a line running as the diagonal showing floor head runs in Plate 9; and suppose $\odot$, E, K, and so on were cut to this line: A, 15 inches below; B, 30 inches below; C, 45 inches; D, 60 inches, or 5 feet below; E will come to the diagonal. Now D being 60 inches, or 5 feet shorter on one side, may be 5 feet longer on the other side of the ship, and it will be readily perceived that the floors are easier obtained; it will also be discovered that the second futtocks would follow the same arrangement, and would not be confined to a certain shape as they now are. The fourth futtock would also follow in like manner, and with like advantages; so of the top-timber or half top-timber; but we see no reasons why this arrangement should be confined exclusively to the floor head. The first futtocks may be adjusted in the same manner, (and with this exception) the dead-flat may be framed as they now are; that frame or any other frame should not butt on the keel, for the following reason—the large bulk of timber in vertical line over the throats of the floors, in addition to the keel below, requires more fastening surface than is obtained from the present mode of construction. By extending the first futtock to the side of the keel, we virtually make a floor timber

of every timber that has a landing or a place on the keel. This would be as it should, and every ship that gets ashore and loses her keel, more firmly establishes the truth of our statement; and we will add, that any mechanic may but examine the socket or seat from whence a keel has been taken, and we are persuaded that he will think as we do in this particular. By extending every first futtock across the keel, we not only distribute the fastening, which adds to the strength of the floors, but make a floor of the first futtocks; by this arrangement the length of the first futtock is increased 7 or 8 inches on the keel alternately, first from one side and next from the opposite side. The head of the first futtock may have the same length of scarf as before, above the floor head, as determined upon below, viz., 5 feet; and as we shortened the floor of frame A 15 inches, we likewise shorten the first futtock 15 inches on A; 30 on B; 45 on C; and 60 on D. It may be argued that this arrangement makes a shorter first futtock; to this objection we say that it is so, but on one side only at the same time; and though the first futtocks may be shorter than they usually are, it matters not; for while we are dispensing with some of the surplus strength between the keel and first futtock-heads, we do so in order

to add the amount thus taken to the bilge, which requires even more than other parts of the ship to render that part equally secure with other parts of the hull.

It is a difficult matter to convince the casual observer that all parts of the ship should be equally strong, or have strength in proportion to the stress that each part maintains, else rupture to some extent is likely to ensue ; but the gradation of butts extends to the second futtocks in like manner, and furnishes the moulder with an opportunity of moulding timber that could scarcely be worked into the frame but for this improvement. The like may be said of the third and fourth futtocks ; and the extension of this systematic mode of distribution is not prejudicial to any part of the entire frame ; and while we repeat that it will furnish a new mode of security to the ship with the same weight of materials, and the same if not less cost, also that we would be less dependent upon certain crooks for particular timbers, than at present. But this is not all ; there is no timber (as far as shape is concerned) but would work into a ship's frame. But it may be asked, why has not this been discovered before ? we say because vessels have not been expanded is the reason ; and the second reason may be found in the fact, that builders repudiate any thing

new, lest it should cost something ; hence, as we have had occasion to remark, almost every improvement is opposed but that of price for building, and the owner is not less at fault ; the cheapest is the best with him ; so long as his ship will insure for A No. 1 he is satisfied, (if we may be allowed to judge from his acts ;) he had rather spend 5000 dollars in extra exterior show to attract and dazzle the eyes of passengers, than to spend half the amount in obtaining an extraordinary strong ship, and in the end the cheapest. But again, those two are not the only parties at fault ; the underwriters are censurable to some extent in not selecting men to superintend their interest in these matters, who are mechanics of the first grade. Sea captains are not the most suitable men to superintend the construction of a ship, (themselves to the contrary notwithstanding,) however well qualified for the spars, rigging, and outfits ; and we think we are right in this matter when we say the insurers have been the losers in consequence of this arrangement. But we have said that this method will cost no more than the present arrangement of the butts ; the making of the moulds of a ship would perhaps require from 2 to 3 days' work more ; the moulder would at first be compelled to move more

cautiously; but working out the frames and putting them together it is quite evident would cost no more; as to the raising and regulating of which, we shall treat in its proper place. They will cost no more, we are quite well persuaded; but all that has been spent by the builder in the loft, and the time of the moulder, will be amply repaid in the facility of obtaining timber to suit his moulds. We have been considering the relative value in dollars and cents, but gold dwindles into insignificance when the better security of human life is to be the result.

Our readers will readily be able to conceive the advantages of this arrangement of the butts, if they will compare the present manner of arranging the butts of the outside plank. Let alternately every other strake butt upon the same frame from the floor heads to the rail, and there will be no difficulty in settling the question at once, that much of the strength of the present arrangement would be lost. The advantages are apparent, when we consider that the system makes no requisition on the room for stowage; unlike the English system of riders, that made such heavy drafts on the room for cargo, it is presented to the world depending on its own merits. But the expansion plan stops not here: having adjusted the butts of the frame,

we may now proceed to divide the entire surface into strakes of proper width; the sheer-lines will furnish data above, and we must not depart from them, inasmuch as they furnish the actual shape edgewise of the plank or strakes, that shows the sheer; retaining the form, we may make such divisions of width as we please. The bottom may also be divided into strakes; remembering that although there is no difficulty in bending the batten on the paper to any division we may make, yet it is vastly important that we so divide the bottom that the plank may be obtained as near the required shape as may be, and at the same time work on the ship easily; and although the young beginner would perhaps hesitate to take the responsibility of lining the plank of a ship, he has now an opportunity not only of planking a ship, but if he goes wrong, he may recover his lost ground without damage, inasmuch as he may make all his marks below the wale with pencil, until he is satisfied that he is right, and then he can mark them in with ink. There are several important things that must not be forgotten in arranging the strakes; we must remember that the smallest girth presented is perhaps some 20 to 30 feet forward of the stern-post, and the largest space to be covered is on the post and cross-seam. Hence it will

appear obvious that the plank should be narrow on the former and wide on the latter part. But again; plank should not be wide above water, and to remove the difficulty, we may butt two after-woods to a midship plank, which will enable us to get up on the stern-post, and even on the transom, with the after-woods, while the butts of the midship plank will be below water. Indeed the opening should be less if possible immediately on coming on the transom than it is 10 or 20 feet forward, else the plank will be widest on the after end, which will appear disproportioned, inasmuch as the wales are tapered, or are narrower on the after end than farther forward; and, as a consequence, other strakes should correspond, or the discrepancy is at once apparent; not only so, but to look well, the wood ends on the cross-seam should measure less on the bevel of the butt than they do farther forward on the square, else they will appear to be the wrong end aft; not only so, but the *sni* will be a derangement in the appearance; the upper edge of the after-woods on the transom should not be round, else the buttock will want the appearance of symmetry, inasmuch as the strakes coming from below have a hollow upper edge, and the strakes above should also be hollow; but although it may be entirely lost and be-

come straight, it should not be round. The wood ends forward on the stem differ very materially both in the required width and shape. First, the opening is much smaller forward than aft; and while we avoid the *sni* aft on the upper edge, we cannot avoid it forward, although it may be reduced very much. The upper wale has a very considerable *sni* or round on the upper edge; this, however, is diminished as we come down, and the manner of doing it is, by making the forward end of the wale narrower. This method of putting on the wales is not general; in very many places ships are built (in this particular) as of old, with the wale as wide at each end of the ship as in the centre. A tapered wale is an advantage, not only in appearance, but in reality, inasmuch as the less we bend the plank edgewise, the fewer grains are cut off in working out the plank to the shape required, and, as a consequence, more strength is retained in the plank when in its place on the ship. There is a deceptive appearance connected with the shape of the plank on the bow of a vessel in particular. The eye may be in a position from which the shape of the plank edgewise may appear straight, when in fact the plank in 40 feet of length from the wood ends may have from 3 to 4 feet of crook; that is to say, that it would require a

straight plank 3 to 4 feet wide in addition to the width of the plank when finished, to furnish the actual shape when on the vessel. The casual observer would suppose from the actual shape shown on the expansion plan, that there must be some mistake about the plan, inasmuch as the sheer appears to be nearly straight. Many men who may be regarded as good mechanics have been thus deceived. This crook edgewise is what is usually termed *sni*, and is consequent upon the twist of the plank, and the higher up on the bow we ascend, the more we have of the twist, consequent upon the increased flare; thus the philosophy will at once appear of making the plank narrower as we ascend toward the rail, where we have the most bend edgewise, and of making them wider as we descend, where the plank can be worked out to their actual shape. There are many ships that have so much flare to their bow immediately under the rail, that the bulwarks could not be put on smoothly more than 3½ inches wide, the bend edgewise is so great. This will be shown by the expansion plan—as we descend, the twist diminishes, and, as a consequence, the *sni* decreases. Hence we discover that it is not only advantageous to the ship, but to the builder and the men who plank the ship, (this part of the work being very

generally done by contract,) to avoid this edge crook as far as is consistent with the shape of the vessel; first, because the ship is stronger; second, because it saves plank; and thirdly, because it saves labor in putting on the plank—the full ship has more of the *sni* than one having less buoyancy.

It will perhaps be well enough to line the upper edge of the lower strakes hollow, else before we are aware of it we shall have the edge round, in consequence of the twist. Were we to line the lower edge of the garboard strake to the exact spiling, and the upper edge straight, we shall find that the strake above would require to be quite hollow on the lower edge. The secret of this crook or *sni* is thus defined—the forward end of the plank on the stem rises perpendicularly its whole width; the bottom may be supposed to be flat, or without dead rise; the after end of the plank, although double the width of the forward end, does not rise, while in the middle of the length of the plank, it has raised more than a mean between the two ends; this, with all the necessary information for planking a ship, is furnished by the expansion plan. True, the liner requires judgment; for example, he should make his strakes narrower on the bilge than on the flat of the bottom, because of the loss in the scantling size of the

frame, by making the bilge straight the width of the plank.

The foregoing remarks will doubtless be quite sufficient, inasmuch as the plan before the pupil will explain itself. After dividing the entire plan into strakes, we may arrange the butts; not, however, for the arbitrary confinement of the butts on the ship, but to familiarize our eye with the best arrangement; and we should approximate as near as the plank will allow, as the plank sometimes determines for us where the butt shall be. We are well persuaded that the apprentice could spend his time profitably in learning to draw an expansion plan of a ship, and we would scarce hesitate to say, that the mechanic would find it to his advantage to improve in that of which he knew but little about, on this expanded plane; few men could be persuaded of the actual form of a ship spread out in this manner. It does not necessarily follow that the straight line for expansion should be straight in the body-plan unless straight on the plane. In Section 4 of Plate 2 we have shown the expansion base-line to be a curved line; and it would have been difficult to understand why this should be so, inasmuch as the base is straight, and runs near the same direction as the ordinary diagonal, which is always straight in the body-plan. But

however paradoxical it may appear, it is nevertheless true, that this line may not be straight in the body-plan, or on the plane expanded.

It will be remembered that we have shown the smallest girth to be from 20 to 30 feet forward of the post. This would seem to have a depressing influence on the base in the body-plan. Again, the largest girth is found at the post, which tends to elevate the line in the body-plan. The fore-body likewise has some peculiarities; we discover the line starting at the same altitude on the $\otimes$ frame of the fore-body, and the frames shortening faster than they do aft, the line is somewhat depressed for a time; at length the flare of the bow causes an elevation in the upper boundary line, and when we reach the side-line on the stem we find a much shorter girth, and, consequently, a depressed ending. Thus we see, that buoyancy concentrated in any part of the ship may have an influence, and this is as it should be. When this departure from the straight line takes place in the body-plan, and, as a consequence, in the expansion plan, it shows that the line from which we expand the vessel was not a perfectly straight line in the direction in which it was taken. This is the case with Section 4 of Plate 2; the line was swept on the model by the edge of the rule staff,

and without reference to its being exactly straight, being only particular to obtain a true spiling. Hence it was only necessary to determine the extent of the curve; and this obtained the base of expansion was furnished. But the method already shown of obtaining this base by two staffs is preferable to that of using one staff first from above and next from below.

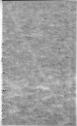
The expansion plan will not only be found useful as an auxiliary in the distribution of the material for strength; but we may be able more readily to determine the surface for the purchase of copper or sheathing, which is not unworthy of notice. Having furnished all the information necessary to project an expansion plan, or to spread a ship out on a plane, we shall next endeavor to show the method of enlarging and contracting models, that is to say: if the model or form pleases us, in what manner or how shall we enlarge or reduce the vessel, and yet retain the same shape through a system of proportions? This knowledge will often be found useful to such as would imitate the form delineated in a larger or smaller vessel; the principle upon which size accommodates shape is strictly proportional, and is founded on the principles of similar triangles; it is a source of inconvenience to those who would increase or diminish the size of

a vessel from that set forth on the draft or model, inasmuch as an alteration of the scale, unless strictly proportional, is an equivalent to a departure from the shape. For example, we double the scale, and the result is, that the vessel is eight times as large; so that it will be readily discovered, that if we would double the size of the vessel, we must not resort to this means of enlarging; neither will it answer our purpose to decrease the size of the vessel in the same manner. If a vessel half the size of another is required, it is not enough that we re-number the scale by regarding that as 1 foot which was before regarded as 2 feet; this again would make the vessel but one-eighth of the size. Hence it must be quite apparent to the discerning mind, that if we would increase or diminish, whether in a greater or less degree, we must adopt some system that can be relied on for all sizes, be the enlargement or the contraction what it may. It should be applicable, indeed equally so, to the spars, or any and every part of the vessel, or any other structure. It is as we have shown, the key-stone of mechanism—Nature's *Vade Mecum*. It is to the mechanic a universal dissolvent. Various methods have been given the mechanical world for increasing or reducing in exact proportion every part of a body or of a ship; but the exam-

ple we have furnished in Plate 13, seems to us to be the one best adapted to the wants, or to the orbital career of this branch of the mechanical world, which, while it is correct, it is easy of application, when the draft of a vessel is to be enlarged or reduced as a draft, only the process is entirely different from that of enlargement or reduction of the same for building purposes. For example, if a draft is drawn upon a scale known as an eighth of the inch, and we wish to draw another or copy that draft, we find it necessary to have two scales—the one corresponding with, or by which the first draft was drawn, the other corresponding with that to be drawn—and by measuring distances on the small draft with the small scale, and applying the same to the large draft with the large scale, we may increase the draft to any size we please; but this has not increased the size of the vessel if built by the draft; and we may build a vessel by each draft, and they would both be of the same size, although one draft might be double the size of the other. When the vessel itself is to be enlarged or reduced from the same model, it is necessary to find the exact relation in the example that the length, breadth, and depth bear to each other, and at which they are to be brought out; or we may, instead of taking the whole depth, take

the altitude of the load-line of flotation above the base-line; and it may not be out of place here to remark, that in all measurements of heights taken in this country, where the point from which we measure is not specified, either the load-line, or the top of the keel, which is usually denominated base-line, should be understood.

In England, and in most parts of Europe, the lower side of the rabbet is the starting point—a most inappropriate place for imparting instruction to pupils. Having once determined the relations of length, breadth, and depth to each other, and at which they are to be brought out if to be enlarged, we may find the length of the model by the scale upon which it was made, likewise its breadth and depth by the same scale. We will now suppose the ship by the model and scale to be 160 feet long, 37 feet beam, and 20 feet deep; the load-line being 15 feet above base line, we want to enlarge the ship to 180 feet long, and yet retain the identical shape after being enlarged, that we had before; we will first determine the principal dimensions by figures, not because it is actually necessary to pursue this course, but because it will doubtless be made more clear by analogizing the two modes. We have the formula in the following shape:—





length	beam	length	beam
160 :	37 ::	180 :	41.63

Again—

length	depth	length	depth
160 :	20 ::	180 :	22.5

Again we have for the altitude of the load-line—

length	foot	length	foot
160 :	15 ::	180 :	16.88

The result is, that the ship of 160 feet long, 37 feet beam, and 20 feet hold, is enlarged by this increase to 180 feet long, 41 feet $7\frac{5}{8}$ inches wide, and 22 feet 6 inches hold, the load-line 16 feet $10\frac{5}{8}$ inches above the base-line. Thus we discover, that though the principal dimensions were increased scarcely 12 per cent., the actual tonnage has gained 30 per cent., for we discover the tonnage by the former dimensions to be 1246 tons, while that of the increased dimensions amounts to 1774 tons. Although this method of enlarging and reducing bodies is in consonance with the principles of geometry, yet it would be a tedious and almost discouraging task to reduce or enlarge a ship by calculations. We shall present another mode, as shown in Plate 13, as adapting itself not only to ships, but to all descriptions of vessels. Assuming a A the length of a ship to be enlarged; $a b$ will also be assumed to be the breadth, and $a c$ the depth of the same vessel; we will next assume $a d$ to be the length required; we now want the proportions that will furnish the proportionate size and shape; and in order

to prove our former expositions. we will assume the same principal dimensions as before, viz.: $160 \times 37 \times 20$ feet deep; let the distance between a A be 160 feet, and the distance between $a b$ 37 feet; likewise the distance between $a c$ 20 feet, and the distance between $a d$ 180 feet, the required length. We thus perceive that a is the stern of the ship in both cases; the ship turning on this point, A is the bow of the ship before enlarged, and d afterward, b being distant from a , the breadth of the vessel must of necessity be 37 feet distant; so with c , that having a locality of 20 feet, the depth of hold from a represents the depth.

We will now suppose the scale by which the draft or model to be enlarged is designed to be the one-sixteenth of an inch; then we have, as in Plate 13, the length, breadth and depth shown upon this scale; from A drop a line square from the first, far enough to meet another line running direct from a , distant from a 180 feet, which by the same scale is the distance required, or the length desired; let a second and third line be dropped from b the breadth, and c the depth, far enough to intersect the line last drawn, the result will be that we are furnished with the new breadth in e , and the new depth in f , which gives the same breadth and depth as before, viz.: e 41

feet $7\frac{3}{4}$, *f* 22 feet 6 inches; but this does not stop here; the proportionate breadth and depth of any line on the ship may be determined. We should not, however, forget that this scale is applicable only to lengths, breadths, or depths; it does not apply to angular lines; if angular lines are required, let them be taken from the plan after enlarged, or let the angle be given, and then strike a line in the projected plan below the base of enlargement at a corresponding angle if within 90 degrees, if without 90 degrees angular measurements will not be required; and indeed they cannot facilitate the work to any considerable extent, inasmuch as the half or whole breadth may be applied from the tables of the model to the scale base of the 160 feet ship; the breadth or half-breadth being known, square the spot down to the scale below of the 180 feet ship, and we have all we want. The mode is simple in principle, and ready in practice, and can be applied by any mechanic who can form a triangle on a sheet of drawing paper margined with a scale on two sides; a piece of veneering formed into a triangle square will be found useful in squaring down the breadths from one scale to the other. It will be perceived that the same relation is sustained throughout. We take all measurements first on the up-

per scale, and squaring them down to the other scale we have the proportionate enlargement, whether the measurement be length, breadth, or height.

We have said that this method for enlarging the draft will apply equally to contract the draft or model to smaller proportionate dimensions, which we will now endeavor to demonstrate. We have seen, that by squaring the length down at the bow, while the stern stood fast, we increased the size as we descended in a continued ratio. Let us reverse the lines, and assume the lower line to be the shortest, which it undoubtedly would be, if we squared from below. Hence it will appear manifest, that if we wished to reduce the ship from 180 feet long to 160 feet long, it would only be necessary to form an angle of 90 degrees below, one line intersecting the upper line in *a*, and the other in *A*, the 90 degrees being only another name for a square; and this theorem is equally true of any other dimensions we may wish contracted or expanded; and in the absence of a better rule, it will apply to the enlargement or contraction of the spars of a ship, as we shall show in its proper place.

The methods used in England, and indeed other parts of Europe, are, in our judgment, less simple, but founded upon the same fundamental principle

similar triangles. That our readers may be able to judge for themselves of the feasibility of each, we will exhibit one method shown by Mr. Fincham, but not as clearly illustrated as it should have been, and will endeavor to make up the deficiency in our illustration.

First find the relation that the length, breadth and depth bear to each other exactly. If the size is to be increased, as in Plate 14, strike in the load water-line, as we have shown on page 43 in the body-plan; inasmuch as this method, as far as heights and breadths are concerned, is derived entirely from the body-plan, the fourth frames of which will be quite sufficient to furnish the proportions we require. This is not all, however; there must be another plan from which to determine the proportionate lengths, and this plan Mr. Fincham has given, which is similar to that already given, but much less clear. Hence it will be seen that our only expositions will refer to the body-plan. We first assume that we have the fourth frames of the body-plan we wish to enlarge; we have also the water-lines stricken across the plan; we next carry out all the water and all the sheer-lines, or their heights, on each frame; we then are required to find the third line of the triangle, that will furnish the height we require. Suppose,

for example, the load-line depth above the base to be 10 feet, and we require 12, we have but to measure 12 feet (starting from the point where a perpendicular from the breadth at the dead-flat frame crosses the base-line) in the angular direction to load-line, that is to say: open the dividers to 12 feet, and placing the first leg at the point shown, and swinging the other leg from the perpendicular direction to the angular, until it meets the load-line, mark the spot, and then draw a line from the point shown below to intersect this point, and continue up until it intersects all the heights leveled out; thus we have a triangle formed, two sides only of which are actual measurements, viz., the perpendicular and the angular; the level lines are only intended as connections, or as an index to refer from the height on one line to its corresponding height on the other. It then follows, that increased heights are found on this angular line, and applied perpendicularly; but this plan applies to heights only; another triangle must be projected for the breadths, and is bounded by the middle-line at the base, and by the point before designated, viz., the connection of the breadth-line with the base, and by the line to be obtained; at the intersection of the frames with the water-lines drop perpendicular lines, that is, at every

crossing of the water-line by the frame, let a perpendicular fall, that from the dead-flat on load-line will be but a continuation of the half-breadth line; a line now extending from this line to the middle-line at base, and corresponding in length with the breadth we require, furnishes the angular line of this triangle; and it will be at once perceived, that at every crossing of the base-line, we have the former actual half-breadth of some frame on a given water-line, and the angular line shows those half-breadths as required, which may be seen by referring to Plate 14. But by Mr. Fincham's rule (if we should apply the well-known adage, viz., that it is a poor rule,) *it will not work both ways.*

If we wish to reduce the size or the dimensions of a vessel, we must pursue a different course from that shown in the rule for enlarging. The water-lines are carried no farther out than the half-breadth line, from which line they shape a different course; so also with their crossing the frames; those points at which they cross extend in one direction no farther than the base-line. In the case of enlargement, the heights were shown to be at right angles with the half-breadth perpendicular, not only at the sheer, but at the water-lines. So also with the half-breadths; they were shown to be in

their extension below the base-line at right angles with that line; in this case, the right-angled corner is formed outward, while before it was formed inward. The water-lines are carried across the body-plan, and no farther in a direct line; the intersections of the frames with the water-lines are dropped no lower than the base-line. Hence it is apparent, that the half-breadth line, and the base-line forming the side of the triangle, has the acute angular connection at each end, while each of the other two sides of the triangles connect with each other at one termination and form right angles, and at the other connect with the half-breadth and base-lines respectively. Hence it follows, that we have only to find the proper relation the breadth and depth bear to each other; and from the outboard corner of the body half-breadth, extend the half-breadth of the dead-flat frame angularly inward; the line at the same time forms an angle of 90 degrees, with another line running in the direction of and terminating at the connection of the middle and base-lines. In like manner the heights of water and sheer-lines form a triangle kind of scale on the outside, or half-breadth line. In the triangle of heights a parallel line is extended from the half-breadth line to the side of its diminished grade, on which all the actual heights may be





seen, as in Plate 14. So also with the half-breadths; they take their departure from the base-line, and run parallel with the outer side of the triangle, meeting the half-breadth side, in regular order. Thus we see that the in-board side of the lower triangle shows the half-breadths, and the lower side of the upper triangle shows the several heights respectively, as shown in Plate 14. The diminished length is obtained in the same manner as we have shown in our own expositions.

The reader scarce needs a single word from us on the comparative merits of those two methods of enlarging and reducing drafts or models, retaining at the same time the same identical shape. If the first method we have described were adopted, we would not hesitate to make the alteration on the floor of the mould-loft after the vessel was laid down. We, however, can scarcely conceive that such a contingency would occur, unless it were determined to increase or diminish the size of the vessel after she was laid down. We say, that in such case we would not hesitate to enlarge or reduce on the floor in the manner we have described, without either making another model or drawing a draft. We are aware that vessels are often altered from the model; but let us inquire how? Are they altered mathemati-

cally, or by geometrical rules, in the United States? that is to say, is the identical shape retained, notwithstanding the vessel is enlarged or diminished? Whatever may yet be done in this particular in this country, we can only say that this has not yet been accomplished, as far as our knowledge extends. We are well aware that vessels are enlarged in a variety of ways, but let us inquire how? Is it not often by adding to the number of dead-flat frames, and making the addition, or the part added, at best little better than a box, and then wonder why a good modelled ship does not perform to our entire satisfaction? We have often heard men express their wonder and surprise at the tardy movements of a ship having greater length than another of more lively motion and greater speed, taking it for granted, that length was every thing, let the shape be what it may.

We say, that when a ship or other vessel is to be enlarged or diminished in size, let it be done in a systematic manner throughout. There is enough of piecing and patching on old vessels, without commencing in the loft. Many vessels have been spoiled between the time of finishing the model and that of making the moulds. There is no difference in the operations of enlarging or diminishing on the floor

of the loft, or on the draft; in the former case, we use the common 12 inch rule; in the latter, the scale upon, or by which the model is made. The operations are identically the same; whatever is feet and inches on the scale, is the same on the rule; and in concluding the subject of enlargement and reduction in the size of vessels, we will add, that it should never be inferred that because the two ends of the vessel is like the model, she will perform much the same, though the middle be altered. We have known ships thus built to be the most unwieldy hulks that could well be imagined; and yet the model, if built by, would have brought forward a fine working ship. It increases the resistance in such manner and ratio, that the builder can determine little in relation to it. The stability, it is true, may be, and is very generally increased, and it is taken for granted that all other good qualities increase in like ratio. Length in ships and most other kind of vessels, we readily agree is a most efficient quality; but let it go where it belongs; let it be distributed over the entire vessel; the greatest proportion in the middle, or yet in the end, will not do; that is to say: that we must not calculate on the performance of a vessel thus altered from the original calculations, without going into the second arrange-

ment, as though the two models were not designed to be alike in any particular. To take from or add to the length, breadth, or depth of a vessel after the building operations have commenced, and expect the same uniform results, is an anomaly in mechanical science; yet the practice prevails to a very great extent throughout the United States; and ship-builders regard, as of little consequence, the addition of 10 feet, for example, all in dead-flats, added to a ship, that it can make no sensible difference. We remember to have heard some expressions of surprise, that two vessels did not sail equally fast, steer equally well, and were unable to carry an equal amount of sail, when it was notorious that they were exactly alike, the one being only 3 or 4 feet longer than the other; it could not be in the vessels; it must of necessity be in working the vessel. Thus the faults of the mechanic are packed on the sailor; and sometimes when the mariner is at fault, the mechanic must bear the blame. An arrangement like we have described very generally comes upon the builder when he is least prepared to meet the emergency. The ship is often required in four months, and the alterations are seldom thought of before the model is made, and afterwards are made upon the floor with impunity. Where the eye determines everything,

the difference cannot be discovered, inasmuch as it is a kind of guessing operation throughout, and we would be quite as likely to go one side of the mark as the other. We are aware that we stand perhaps quite alone in this matter of enlarging at random; but we had rather be alone, when conscious of the right, than on the popular side, and in the wrong. As we have doubtless made this subject sufficiently clear in the preceding chapters, no farther expositions are required.

We left the floor of the loft the second time on page 183—having little more to do before entering upon the important duties of laying off the cants and other important parts of the structure, until the reasons were given for adopting the independent course we have taken in designing, as well as in laying off ships. It is not enough to know how a thing is done, the why is often of equal consequence; and to pursue the course others have done, viz., to go into the loft and not leave it until the whole operation is performed, we should judge would be much the same as though the mechanic who was laying down the vessel was to continue his work without reference to the vessel itself, either in size, space, or adjustment.

Having carried the several opera-

tions along together as near as we could on the model, the floor, and the draft—not, however, by leaving either in a crude state—both the draft and the floor delineations were carried through the second proof, or were first transferred to the floor from the tables, faired in the rotundity of their longitudinal planes, taken from thence and applied to the body-plan, the discrepancies regulated in the body-plan, and the corrections noted on the floor, and the water-lines again faired and made to correspond with the frames of the body-plan. This operation constituted the first proof, and if the necessary care were taken in the performance of the work, the ship would come to the ribbands easier than many vessels we have seen that had been carried through the second proof with the aid of diagonals. The draft also was carried through the several stages of advancement, and we now are brought to the threshold of an inquiry, what yet remains to be done upon the floor, before we are ready to make moulds? We answer, more than can be described on the remaining pages of this chapter.

We have carried the lines on the floor through the usual test of their accuracy, and we may fairly assume that the ship is delineated in her full size; and doubtless more might be learned by the casual observer of her

real shape from the floor now than at any subsequent period, after a more copious effusion of lines has taken place. The body has been faired by horizontal sections, usually called water-lines; vertical sections, usually called section or buttock-lines; and by oblique sections, usually called diagonal lines. The sheer and half-breadth plans have been divided longitudinally into equal spaces the entire length of the ship; a section or part of each extremity has been set apart for the cants or half-frames, standing diagonally from the middle-line; the remaining or mid-ship portion of the ship's frame will stand at right angles with the middle-line, or square across the ship; and it might be supposed that it will only be necessary to sweep in the frames with pencil in the body-plan, and at once commence making moulds for the square body. This practice is quite common, but we will pause and inquire into the propriety of adopting it. We have shown that a broad surface should be presented to the timber, for the better distribution of the fastening, even though it be at the expense of the scantling size of the timber. These reasons apply equally well to the frame composed of two timbers as to the single futtock or timber; but it has been found to be advantageous to the ship to make the distribution of surface still

more general; and in order to accomplish this successfully, the spaces between the timbers of adjoining frames, and those of the same frame, have been about equally divided, and the change has been attended with beneficial results. As a general rule, however, the spaces between the timbers of the same frame is somewhat less than that between the adjoining frames; but for this inequality in room or space, we are fully persuaded no substantial reason can be assigned, inasmuch as the fastening and the ventilation of the ship is much better accommodated, where the room between the timbers and the frames are equal, apart from the advantage of having the plank more equally supported. It will readily be discovered, that to separate the timbers as has been described, will be to make two moulding edges to each frame, which if the ship has a number of dead-flat frames, would not alter their shape; but just in proportion as we recede from the dead-flat frame, will the moulding edges be found to disagree; and if we were to move both timbers of the frame from the station, equally divided on the base and middle-line, we should require a new division, or that frame to be newly spaced. But the necessity of this may be avoided by allowing the floor, second and fourth futtocks, with the half top-timber, to re-

main, and move the other half of the frame the distance of the opening ; that is to say—let the first futtock, third futtock, and top-timber, be moved just the amount of the opening ; if the floors face, or have their moulding-side toward the dead-flat, both in the fore and after-body, then the first futtock will require to be moved aft in the fore-body, and forward in the after-body ; in this case, the first division of spaces should have furnished the dead-flat frame with a larger space between itself and A, (or the first frame in the fore-body,) inasmuch as the other floors have between their faces or moulding-sides two timbers and two spaces, while by making two floors face together, we bring two timbers and three spaces into one berth ; hence it must be quite apparent, that between ⊗ and A we require more space on the keel, and, as a consequence, on the floor, by just the amount of space the frames are designed to be apart, than that of any of the other square frames. We have known the frames of a ship to be arranged equal distances apart, and all the floors to face forward ; but the liability to mistakes in bevelling the timbers is much greater when this method is adopted, for the following reason—the floors in the fore-body bevel standing, while those of the after-body bevel under. This arrangement, it will

be at once perceived, reverses the bevells of all the timbers in the fore-body, which makes the operation inconvenient, inasmuch as it subjects the operative to the liability to mistakes, in consequence of his having been accustomed to bevelling all the timbers of the same denomination within or without the square, as the timbers upon which he may work may demand ; in other words, workmen have been accustomed to bevelling all the floors under, and all the first futtocks standing : this is the result of facing all the floors to ⊗, which frame also faces forward, being in the after-body, or being usually recognized as belonging to the after-body. With this arrangement, the face of the floor is at the place or station at which the moulds are designed to be made ; and it follows, that whatever variation there may be in consequence of removing the first futtock and the timbers butting on above, from their proper place, or the place where their moulding-edge was laid down, must belong to the first futtock. This variation does not amount to any very considerable amount for perhaps 10 or 15 frames from the dead-flat, when it becomes worthy of notice, and measures should be taken for removing the discrepancy. It is quite common to make but one set of moulds for the entire square body of a ship ; that is to say—that the first

floor-side of the frame. As we have also stated, this practice is rarely adhered to the entire length of the square body, and to avoid the cost or trouble of doing this, the chocks are often made thinner than they would otherwise be. With the arrangement as we have described in the distribution of timber, the ship is not only actually stronger, but nearer the shape she was designed to be.

We have thus carried our readers through the operations of the floor in relation to the square body of the ship, or those frames that have floors appended to them, and stand at right angles with the keel. It is sometimes the case, however, that it is not necessary to commence the canting of the frames, and yet the frame has so much rise that we cannot obtain floors; this may be known before the cants are laid down, and the arrangements made accordingly. Such are called box frames, and would be framed and boxed, or morticed into the dead-wood at their heels, in the same manner as the cants, but still stand thwartship, or at right angles with the keel. These frames may be, and are sometimes found on each end of the ship at the same time, or on both ends of the same ship; although box frames are properly square frames, yet they may with propriety be classed among the cants, for these reasons—

the order of framing is changed on the floor frames; the timber boxing in or across is the floor or short timber, that is to say, short on each side; but on these box frames, the timber boxing into the dead-wood is the long timber, or first futtock; and this is the same as the cants. But although this arrangement is quite common, we can discover no good reason for the change; when there has been carelessness in the loft, and an equal amount in framing, perhaps the change is an advantage, in consequence of the liability to difficulty with the heel against the side of the dead-wood, when the frame goes up with both heel timbers on; in such cases the short timber is left off, and put up afterwards. Another reason, however, is usually assigned, which is this—that the frame is rendered stronger by boxing in the longer timber; this we regard as a mooted point, and shall leave its settlement in the mind of the builder, being satisfied in our own mind that it is of no material consequence, whether the long or the short timber is boxed into the dead-wood. This should be remembered, that the timber that stands fast on the floor of the loft, is the floor-side of the frame, remaining stationary, while the first futtock side of the frame moved the thickness of the chock; on the box frames we may box in which we please. These

frames are equally as strong as cant frames, and sufficiently so for their location, if properly fastened to the dead-woods at their heels. There are seldom more than two of these frames at each end of the ship, and only where little cant is required to fill the opening above. The heels of the timbers of these frames end at the bearding-line, and have no connection with the line showing the seats of the floor, as seen in Plate 8.

We have but one other exposition to give in this chapter in relation to

the square body-plan on the floor of the mould-loft, believing that the subject has been made clear to every discerning mechanical mind. In taking off the frames from the half-breadth to apply to, and sweep in the body-plan, we should work by the diagonal lines, inasmuch as they come nearer at right angles with the shape of the frame, even though taken off horizontally, and the nearer square, measurements are taken, the more likely to be correct.

CHAPTER VIII.

Cants by Water Lines—Cants by Diagonals—Square Stern, without stern frame—Its Advantages—Stern Frame—Instruction for Building them—Making Moulds.

We have shown in a previous chapter that the square frames do not extend the entire length of the vessel unless she is very sharp, like some of the steamboats running on the Hudson River; we have also shown the reason for adopting the system of cant frames in this country some fifty years ago; and although we invited the reader to follow us in taking off the tables from the square frames extending the entire length of the ship, yet we had no intention of making moulds by the frames swept on the floor to the entire extremity of the ship; hence the reason of our setting apart a space at each end of the ship for cant frames, as shown on Plate 3, and on Plate 7. The judgment of the builder must determine the number of cant frames required, and the angle of obliquity they form with the middle-line, or side of the keel. This obliquity must increase as we approach the extremities, and still meet the varying form of the ship.

The disposition of these frames may be seen in Plate 16, in the half-breadth

plan. Our remarks on expansion may be referred to with advantage to the reader, even though he may have built ships. The distribution of the timber on the ends of the ship, is a matter of some moment, both with respect to economy and strength.

The disposition of cant timbers or frames may be familiarly illustrated by the swinging of a door upon its hinges, with this exception: the door is continually hanging upon an immoveable axis, while each cant has its own axis. Assuming a door to be open to an angle of 90 degrees, which is square from the partition upon which it is hung, while in this position it represents a square frame, the line of partition representing the keel. Let the quadrant or quarter circle formed by the outer edge of the door be divided into as many parts as there are cants; now close the door to the first division, and we have the angle the door forms with that part of the partition to which the door is hung, that the first cant does with the keel from forward. The same

may be said of any and every other one of those divisions; when we have the stern frame in the ship, we do not cant as far, but when we have a round or square stern, without stern frame, we cant the whole number of degrees the quadrant or quarter circle contains. Many persons have thought that the canting of frames must of necessity swing them from a perpendicular line on the dead-wood; now suppose we examine and find that the door was plumb on both edges, or at the hinges, and at edge upon which the lock is placed, we now mark a parallel line eight inches from the hinges toward the outer edge; let us open and shut the door, trying the line on the same, in the different parts of the circle, we shall find that in any position we may find the door, the line will still be plumb. Now it is just so with regard to the keel; although the axis of the cant is at the centre, yet at any given distance from the centre the cant on the dead-wood is square, while the dead-wood or its sides are plumb; and if they are not plumb, they should be. Hence we say emphatically, that all cants should be square from the base-line; but we may illustrate something more by the door. We have seen that all lines that are parallel to the axis are plumb; but now let us mark out the form of a frame on the door end-

ing the heel six or eight inches outside of the hinges; open the door as at first to 90 degrees from the partition or square; mark a line on the floor nearly parallel with the partition, that is to say—let the widest part be at the edge of the door when open, and taper as the side of a ship would taper, toward a line squared out from the edge of the door when shut. We may divide the sill of the door into as many parts as the circle has been, when we have the whole mystery of cant frames illustrated. We discover that the door, although it will fill out from the hinges to the circle at any angle, yet we may shift the axis to any of the settings-off corresponding to those of the circle, and we shall see that the edge of the door will not reach the line representing the side of the ship. Hence it is plain, that although the ship is growing narrower the farther aft we go, yet the frames require to be longer, on account of the increased cant, that is to say—the canting increases their length faster than the diminishing of the side shortens them, which would be the case were they square frames.

The wonder we think must cease when the subject is fully considered in the manner we have described. European authors have confused the subject of cants or canting frames by connecting so many lines with the process

of instruction. The mystery of cant frames is not as great as their expositions would seem to indicate, (judging from the number of lines made use of or employed in the operation.) They first endeavor to show us how to lay off cants by what they term level lines, or lines running parallel to the base-line; and again, by a second set of lines they term water-lines, as though all lines, whether running parallel to the keel or to the surface, were not water-lines. We would like to know what need there is to make a distinction in lines that should be exactly alike, particularly in illustrating this subject, unless it be to confuse the mind of the reader. We have endeavored to divest the subject of everything that is not absolutely necessary to illustrate the matter fully.

It is true we will show the manner of laying off the cants, both by water-lines and by diagonals, but this is necessary, inasmuch as vessels may be built without the use of diagonals, although a valuable acquisition in the loft for the purpose of proving frames; and again, in the third series of lines we shall show the advantages of laying off cants, by the section or buttock-lines, as they are sometimes called.

As we have before said, we must dispose of the cants first in the half-breadth plan, where they are seen as

straight lines; they may also be seen in the sheer-plan, but are not necessarily so, unless in some more than ordinary cases. We may show their shape in the body-plan, or we may make a cant plan on a separate part of the floor, as shown in the draft, Plate 7. It is seldom, however, that this is rendered necessary, inasmuch as the body-plan is sufficiently large to keep the cant within the square frame under ordinary circumstances, or when we have a stern frame. Hence we discover that it is more convenient to use the square body when we can. In cases where we determine to have no stern frame, and yet have a square stern, we would recommend a separate plan for the cants, as shown on the draft, Plate 7. It must be remembered, that in laying off the cant frames, the side line, although seemingly a fictitious line, is really the size of the keel in the direction in which it is shown; and that we require a different side line for every cant. Thus we perceive that we have no connection with the original side line used for the square frame, inasmuch as we have shown by the similitude of the door, that although the side tapers as we approach the stern, the frames continue to extend farther out as we continue to cant them more. It is even so with the side line, in one particular at least; the exception may be found in

the parallel thickness of the keel. The ending of a cant is somewhat analogous to the ending a diagonal line swung off as we have shown; the variation is found in the direction, or the angle upon which the keel is measured; and although some of the cants may extend outside the square frames, it should not surprise the inquirer.

The practice of drawing drafts and of building ships with a drag-line in Europe, has seemed to envelop the subject of cant frames in mystery, or at least the subject has been made much darker to the mind of the learner than it would otherwise have been; we mean by the dragline greater draught of water aft than forward, the consequence of which is, that the load-line is not parallel to the base-line, and the water-lines form a curved line in the body-plan, and, consequently, the lines on the cants alter their heights; which adds to the complexity of the subject. This practice has been abandoned in the United States, or at least in the general sense, and, as a consequence, the lines are found to be parallel to the base-line. In view of this arrangement, it must be quite clear, that in swinging the cant around from the position of a square frame, the lines neither rise or fall, that is—the water-lines on the bow do not find a lower place on the frame, neither do the after cants, when swung

around, cause the lines to rise on the frame, in order that their proper height may be obtained. The sheer-lines are found to be higher on the cants than on the square frames on both ends of the ship, inasmuch as the bow and stern are both higher than their respective square frames; the consequence of this rise makes it necessary to square up from the half-breadth plan the crossing of the cant on every sheer-line respectively; in other words, in the half-breadth plan, where the cant crosses the first breadth; take the distance of that spot from the last square frame, and carry that distance up to the sheer-plan, and mark on the first height the same distance, so of every other cant and sheer-line; the crossing being noted in the sheer-plan, the heights may be taken on the respective cant frames, and carried to the body-plan, and being lined across as in the case of square frames, the body-plan is prepared for the half-breadths. In drawing the draft it is usual to square up the crossing of the water-lines to the sheer-plan, that is to say—the spot where the cant frame in the half-breadth crosses the water-line is squared up to the same line in the sheer-plan, where its crossing is also marked; the crossing of the side line by the cant is also squared up to the sheer-plan, and marked on the bearding line; a batten applied to

these several spots will show the square view of the cant frame ; this line, however, is seldom required in its full length on the floor of the mould loft, although it not unfrequently occurs that some one or more of the spots are required for the purposes of proof, &c.

We have shown the manner of striking in the cants in the half-breadth, that the openings be regulated on the top-side, or on the first breadth, and that there be sufficient room for the heels against the dead-wood. If the ship be full, we are apt to crowd so many cants in, that the heels require to be tapered, whereas had the ship been sharper, we might have had a sufficiency of room. It would be better to have room enough for the heels to be kept apart, even though we had to put in more timber above. It is even more essential that cant frames should be kept apart by the introduction of chocks than square frames. It is quite recently that chocks have been introduced between the moulding edges of cant frames, although it has been practised in Europe, but not to any considerable extent ; but we say, that the chocks should be thicker at the head than at the heel of the frame, making the distribution more equal. It may be objected to, on the ground that a tapered chock would be difficult to fit, inasmuch as the thickness is only parallel at parallel dis-

tances from the centre or side-line. To this objection we answer, that it would be an easy matter to mark a parallel or plumb line on the mould at the sirmarks, and we have all we require ; the advantage of such an arrangement to the ship would be more than an equivalent for the trouble.

In a former chapter we have shown another manner of disposing of the surplus timber below on the cant frames, by substituting a single timber for the frame. This would be much better than the present method ; but in either case, the chocks between the timbers of the frame should not be dispensed with, and we may make the chocks to taper or parallel as we please. If we adopt the chock, we must line their thickness in the half-breadth plan, and proceed in the same manner to take them off that we did the square frames. When we took off the half-breadths in the square body, we applied the batten on the line showing the frame ; we do the same in this case, by applying the end of the batten to the middle-line : the batten extending along the line showing the moulding edge or joint of the frame spotting on the batten, the line we desire to take off ; this is applied to the body-plan in precisely the same manner that a square frame would be. This operation must be performed on each side of the chock, and the frames

may be swept in with pencil and red chalk, to distinguish them as in the example of the square frames.

In arranging the cants in the half-breadth plan, there are two things to be considered, both in the forward and after-body, in addition to the ordinary size of openings; and although the subject we are about to introduce has found its way into separate chapters and articles by cotemporary writers upon this subject, yet we believe it requires a notice in this place, inasmuch as it is immediately connected with the division of the cants in the half-breadth plan. For example, the stern frame is immediately connected with the cants, inasmuch as the after cant timber forms the boundary line of the stern frame, and is commonly known by the name of fashion piece; the moulding-edge of this timber defines the length of all the transoms; and if we adopt the prevailing custom of canting the frames but little, the fashion piece would have a place on the side of the ship, as also the end of the main transom, some few inches of which is usually shown on the first breadth, or about half of its size on the end. With these remarks before him, we think the pupil will be better qualified for dividing the half-breadth of the after-body.

We have said that the fashion piece was a single timber; it is not neces-

sarily so, unless we so determine, as we shall show in the proper place; we will add, however, that it is not a cant frame, but belongs to the stern frame, although its location must be shown before we can arrange the cants; that is—if we determine upon the usual size and mode of building it. Thus much for the interruption on the stern or after-end of the ship.

The remainder of our remarks were reserved for the bow of the ship, although the forward cant in the fore-body is not confined in the manner the fashion piece is in the after-body, yet it has a connection that is worthy of our notice, inasmuch as the opening on the rail may lead us to suppose that we may equalize the division between the frames. This need not be done. There are other timbers that have a place in, and form a part of the bow, the heels of which are cut off by the side of the forward cant; hence it must not be inferred that the cants are designed to fill the entire space unoccupied by the square frames; the knight-heads and hause-pieces heeling against the forward cant, admonishes us that a portion may be reserved to advantage for those timbers, a detailed account of which will be found in this chapter. With these distributive remarks relative to the cants, we proceed without delay to the continuation of

the taking off process. It is assumed that the lines are rendered perfectly fair before we begin to take off the cants, having been proved by the water, diagonal, and section-lines, in connection with the continued square frames that were extended to the extremities. Hence it only remains to take off the cant frames, or their distances on the cant from the middle-line to the respective lines, and set off in the body or cant plan in the same manner as applied in the square body.

In this exposition of the cant frames, it may not be necessary to go as fully into the various modes of obtaining the bevels of the cants, as in the remarks connected with the cants by diagonals. In the half-breadth plan the practice has become quite prevalent of setting off the size of the timber each side of the joint or moulding-edge, as shown in Plate 15. In this case, to the line showing the joint of the frame when there is no chock, (as we have said chocks in the cant frames are of recent date in the United States,) a square is applied to this line showing the joint in the half-breadth, the stock with the line, and extending to the intersection with the middle-line. At this junction the tongue of the square is first one way and then the other, or first up and afterwards down; this, of course, makes a line at right angles

with the joint of the frame; the size of the timber is then set off from the joint each way, both forward and aft, and the half-breadths taken off a second and third time, and applied in the body-plan; that is to say—from this square line the batten is applied on each of the last two lines representing the bevelling edges of the timber. It follows, as a consequence, that one line will come within the moulding-edge, and the other without; or we may express it different—one line will come aft and the other forward of the joint; that is to say—the one will bevel standing and the other under, for this reason: it will be observed, that this method is virtually trying a square across the frame, to see the amount of bevel given by the gathering in of the lines. It may be thought by the reader, as it has been often expressed by the inquirer, why not apply the square in the half-breadth plan, and avoid all, or a portion of this work, by taking the difference from a square within or without, and applying the same to the bevelling board, so many lines might be saved, and thus the liability to mistakes prevented? We have often listened, or at least more than once, to questions like the foregoing; and if the reader will be quiet, we will tell him in a few words the objections to his proposed plan of taking off the bevellings.

It is well known to those who have worked out a ship's frame, that the only correct method of applying the bevel is, that of placing the stock as near at right angles with, or square from the moulding-edge as may be, the tongue will then incline neither way; and if a square were applied to the tongue from the face of the timber, it would be found to hang down at right angles with the face. It is also well known that if the heel of the stock be turned either way, or in either direction, the true bevel cannot be applied without much trouble; and we may safely say, that for general purposes, it is not correct. Hence it follows, that the bevel to be taken correctly, and applied equally so, must be taken square from the moulding-edge, and this can only be done in the body-plan; that is to say—no one set of lines running longitudinally will cut all the frames at right angles; although the diagonals come much nearest, yet they are not reliable to furnish the bevels in the manner we have shown, or in the direction of the line. The lines in the body-plan showing the bevelling edges of the timbers, may, and indeed should be swept in with white chalk. Then there need be no mistakes; the two inner lines show, the one the moulding, the other bevelling edge, and whatever the one falls within the other, when measured square,

this will be the bevel, as in Plate 15; thus it must be apparent, that if the spots are carefully made, and as carefully applied, there can be no doubt the spots will furnish a fair line in the body-plan, and the bevel can be taken off anywhere at any spot we please, remembering that by this method, as indeed all methods from the body-plan, when the white chalk line is inside the black or red line showing the moulding-edge, the bevel is under, when without, the bevel is standing, and where they cross each other, there is no bevel, the timber is square. We are aware that we are departing from the usual course in bevelling cants, before having even proved them, but we are also aware that the stiff stereotyped custom of European Naval Architects, has prevented the young and inquiring aspirant from holding the thread of reasoning their pages contain; hence the reason why we have followed up with the bevels, believing that one will assist to explain the other.

We think enough has been said relative to the manner of taking off the cants by water-lines; we may or may not prove them, as we please; they are not generally taken off by water-lines, and when they are, they should be proved by section-lines; particularly the after-cants. We have shown the manner of squaring up the crossing of

the water and sheer-lines by the frames, and of sweeping the curve by those spots; this is termed the thwartship view, or the actual shape presented to the eye when abreast the station of the cant on the keel. We have said that it was not necessary to sweep them in on the floor, and only on the draft; we may add, that if we would show the cants as swept by water-lines in the manner described, and proved by section-lines, we cannot well dispense with those thwartship views in the sheer-plan. The manner of proving the cants by section-lines is not complicated; the section-lines have been shown in the sheer-plan in Plate 4, where they cross the frames, as shown in the square view; there the height must be taken and applied to the same frame, and on the same section-line in the body-plan. The manner of running the section-line in the half-breadth body and sheer-plans, has been explained on page 136, and onward; or as we have before remarked, that if the spots only are necessary, the line need not be run in to exhibit this cross view in the sheer-plan. We are aware that more lines on the floor than is absolutely necessary, is objectionable. We may apply this proof by taking the height on every frame, and on every section-line, and if they agree, they are correct, without doubt. In-

asmuch as the cross-seam intercepts all intercourse between the section and sheer-lines in the after-body, we need no farther proofs above the outer section-line, because the round of the side on the breadths or longitudinally, is so small that it can hardly be imagined that any discrepancy should exist, if proper care has been taken in the transfer.

It may be fairly assumed that enough has been said in connection with the illustrations given, to make the subject of cant frames by water-lines sufficiently clear to the thinking-man; and we now enter upon the duty of giving expositions upon another method of delineating cant frames upon the floor, and upon the draft, which we think we hazard nothing in assuming to be more practical. We have already explained the position and angle of cant timbers in the three plans, viz., sheer, half-breadth, and body-plans. We would here remind the reader of a striking feature, to which we have referred in cant timbers—it is well known that in square frames if the frame were cut by the line furnished in the sheer-plan and half-breadth plan, that it would show the actual shape of the frame, and yet the line would be a straight line in both plans. This, as we have observed, is not the case with cant frames; they cannot by any possible means exhibit a

straight line in the sheer-plan. The eye, it is assumed, moves no faster than the stations on the side-line would require, which would be 90 degrees, or square from the keel; hence it is plain, that although this position would exhibit a straight line in the square body, the canting must form a curved line in the sheer-plan; and the greater the cant, the more curvature will be shown in the sheer-plan. This matter of exhibiting the form of cants on the floor, is rarely attended to; but on the draft the principle of canting cannot be fully explained, unless attended to. Lest by dividing of the half-breadth (or that portion set apart for cant frames) into double sections to admit of chocks between the timbers, we should confuse rather than instruct, we will first lay them off as though the moulding sides were to come together. We must first observe the crossing of the diagonal by the cant we are about to take off. It will be remembered that the diagonal line in the body-plan forms a straight line; we must take off the cant from the spot where the crossing takes place to the middle-line square, so that the distance from the place of crossing to the middle-line will be shorter than any other direction we could possibly find; this, as a consequence, will be square. We will now apply this to the body-plan in the same manner, by holding

the batten horizontal, and moving it up or down, until the spot we have taken from the half-breadth intersects the diagonal, and at the same time the end of the batten is at the middle-line, mark this intersection horizontally across the diagonal, and several inches outward; we then take the batten again to the half-breadth plan, and apply it in the direction of the cant along the straight line showing the frame; the end of the batten as before at the middle-line, mark the crossing at the same identical spot on the floor we had before on the batten, the only difference being in the place of the heel against the middle-line; take the batten again to the body-plan, and apply it in the same place as before. It will be discovered that the spot on the batten extends farther out-board than before; mark this spot last taken on the line we made when here first; this spot is the actual breadth when the cant is in its place. The first breadth taken is the actual half-breadth of the ship at the station of the cant on the side, or square from that point, on a line running into the middle-line, and square with the same. The operation we have shown must be performed with every diagonal line. The philosophy of this operation is as follows—the diagonal in the body-plan takes its starting point from the middle-line; hence it follows, that inas-

much as the stations of cants are square from the base-line in the sheer-plan, it follows that the diagonal must have the same application, or bear the same relation to the cants, so that when we apply the diagonal to the cant frame, they are or should be understood as being both in line perpendicularly from the base-line, and at the proper station on the side-line, or side of dead-wood. Now it must be quite apparent, that as the cant is swung aft on the stern, or forward on the bow, we bring the station of the cant to a part of the ship where the diagonal is higher than if the frame was square; not only so, but the ship is narrower at this new breadth; and we shall discover that the farther aft in the after cants we proceed, the greater will be the difference between the two breadths, viz., the canted and the square breadth. All the diagonals being taken off, we may square up the crossing of the sheer-lines on all the cants up to the sheer-plan; transfer the height so obtained to the middle-line of the body-plan, through which point draw a level line. In the half-breadth plan take the distance in the direction of the cant timber from its intersection with the sheer-line to the middle-line; apply this half-breadth on the height to which it belongs in the body-plan, and continue the same operation on all the sheer-

lines. Having shown the manner of obtaining the form of the moulding-edge of the cant frame without the chock, we may proceed to delineate the manner of performing the same with the chock.

It will be remembered, that in our arrangements for the admission of the chock in the square body, the original line at which the floor was placed was permitted to stand or remain unmoved, while the moulding-edge of the first futtock was removed its proper distance from the floor. The same or a similar arrangement will apply to the cants; the moulding-edge we have laid down may remain, and the thickness of the chock may then be set off, inasmuch as it is the custom to reverse the order of the cants; from which we shall discover that the line we already have in the cant body-plan is the first futtock. The thickness of the chock may now be shown by another line being stricken in the half-breadth plan, aft (if in the after-body) of the original line; they may be tapering or parallel, as we please; and the same operation may again be performed in transferring the form of this line also to the body-plan. These two lines are the moulding-edges of the cants, and may be distinguished by the color of the marks upon the floor and upon the moulds. We now want to determine the bevel, inasmuch as the



the same way as in the case of the first operation. The only difference is that the second operation is performed on the second side of the plate. The result is a plate with a double thickness of the material.

It is now necessary to consider the case where the material is not uniform in thickness. In this case, the second operation will be performed on the side of the plate which is thinner. The result will be a plate with a uniform thickness.

The next operation is to perform a third operation on the plate. This operation is performed on the side of the plate which is thicker. The result is a plate with a uniform thickness and a double thickness of the material.

The final operation is to perform a fourth operation on the plate. This operation is performed on the side of the plate which is thinner. The result is a plate with a uniform thickness and a double thickness of the material.

The result of the four operations is a plate with a uniform thickness and a double thickness of the material. This is the final result of the process.

The next operation is to perform a fifth operation on the plate. This operation is performed on the side of the plate which is thicker. The result is a plate with a uniform thickness and a double thickness of the material.

The final operation is to perform a sixth operation on the plate. This operation is performed on the side of the plate which is thinner. The result is a plate with a uniform thickness and a double thickness of the material.

The result of the six operations is a plate with a uniform thickness and a double thickness of the material. This is the final result of the process.

The final result of the process is a plate with a uniform thickness and a double thickness of the material.



bevelled edge of cants, or the amount of bevel they require, may and should be determined at the same time; or in other words, one follows the other. In our delineations of the performance of this part of the work by water-lines, we squared a line across the joint of the frame at its connection with the middle-line; this line extended the siding size of the timber, both above and below, or aft and forward. This we described as the custom very generally adopted. We shall in our expositions of this part by diagonals pursue a somewhat different course. At the confluence of the joints with the middle-line, we may square up, but not down, as we have no occasion for crossing the middle-line. We may now apply a straight edge across the timber, or its space on the floor; square from the joint of the same, or the straight line showing it—selecting the roundest part of any of the lines in the end of the ship in which we are at work. The object of this operation is to determine how far across the frame it would be safe to take a bevel, in order that the same may be reversed and apply equally well to both timbers. It is quite evident, that if the straight edge were carried or applied the whole siding size of the timber, and if the bevel this would furnish were reversed, it would not be at all adapted to the opposite tim-

ber of the same frame at the same sirmark. Now suppose the siding size of the timber to be 10 inches, it must be apparent that we could not accomplish our purpose of obtaining the bevel of both timbers by taking all the bevel of the one timber, and reversing this bevel for the other timber of the same frame and at the same sirmark. Hence it will be observed, that the smaller the distance taken across the line, the nearer will the bevel apply to the opposite timber of the frame when reversed. Thus we may observe, that six inches may be adopted instead of ten from the moulding-edge, or face side of the timber, (and we have applied this method to vessels where even three inches were an abundance,) the smaller the circumference of the curve, the smaller the space required for reversing the bevel.

It will be observed, that this method, although far preferable to the one before delineated, in connection with cants by water-lines, is only applicable where there are no chocks, or where the chocks are small. The method we have referred to is not confined to water-line cants, but is equally applicable here. Having found at what distance from the face the bevel may be taken, in order that it may be reversed, we may strike up a parallel line to the joint line. As we before remarked, the distance is consequent upon the bevel

when reversed, as the design is that the bevel shall apply equally well to both timbers of the frame. If for example, the frame upon which we are determining the bevel, be in the after-body, it follows that we are determining by the bevel taken from the forward timber say six inches from the face; that is to say: how much bevel has the forward timber, provided it was sided but six inches? This being determined, set the bevel to the amount; apply it to the timber, or to its space on the floor, which is the same thing; ascertain how much it would take off the forward or bevelling edge; reverse the bevel, and apply it to the space that would be occupied by the after timber; and if it would require more to be taken off the bevelling edge than off the forward timber, or less, we evidently bevel too much or too little on the forward timber; that is to say: six inches is too much, or not enough. We may thus arrange or adjust the bevel by applying the straight edge in several places or parts of the body in which we may be at work.

It should not be forgotten to apply the batten both ways in taking off the bevelling edges from the half-breadth plan, in the same manner that we did the moulding-edge, inasmuch as this edge, or the assumed six inches requires its own sirmark on the diagonal: what-

ever the rising of the diagonal as we approach the centre may be, it must be noted, and the sirmark raised accordingly. Thus we discover that each setting-off as a half-breadth must be applied to its own sirmark. When we have found a distance that will furnish not only the bevel of the timber from which it was taken, or for the half-frame to which it belongs, but being reversed, will apply equally well to the opposite timber, we may take off as described, first the rise of the sirmark, which must be carried out level in the body-plan, then the half-breadth on this level line; the bevelling edges may be swept in the body-plan with white chalk; after which, a bevelling-board may be prepared to the size or width we have determined upon, as the given distance in which the bevel is obtained. We may remark, that in all probability this would in no case be less than two and a half inches, or more than six. The larger the vessel, that is, at the same time full, the nearer we approach the latter size or number, while on the other hand, the small full sloop or schooner would not require more than two and a half inches. The principle lies just here—the mean of a given distance on the circumference of a barrel-hoop will be more than on that of a hogs-head-hoop in the same distance. This seems to be paradoxical at the first

glance, inasmuch as the quick curve requires but a small setting-off; and yet a vessel still fuller may require less. This is very possible on account of the great difference in the size of the vessels. On the small vessel the timber may be sided only six inches, while on the large ship it may be sided ten inches or more. Thus it will be seen, that if we took as much for the small vessel, though even less round than the lines of the large ship, we would have the whole size of the timber. There can no rule be given that will apply in every case; the judgment must determine the distance to be taken, let the distance be what it may. The bevelling-board must be of the same width, having the diagonals and sheer-lines in the cant as well as square body-plan; they are equally as applicable for sirmarks or bevelling spots, and may be marked on the moulds, remembering that the mould is to be made to the blue or red line, and that the spot where the level line crosses the moulding-edge is the sirmark to be marked on the mould; the diagonal is found to be (the distance between the line levelled out, showing the same as it now is,) above its former place caused by swinging the frame round from a square, or consequent upon the frame having been swung round to its place. Thus the floor we perceive will not regulate the frames to

their proper places, like the draft; they treat all frames alike, keeping them all on a plane; hence it is important that those discrepancies should be noted and attended to.

Having shown the manner of laying down the cants by diagonals, and preparing the bevelling-board, we will next notice the manner of taking off the bevelling of the cants. It will be observed, that we take the bevel from the after timber of the frame if in the fore-cant body-plan, and from the forward timber if in the after-cant body. Hence it is quite clear that whether the bevel be standing or under, it is the timber we have described, and is known by the body it is in, whether forward or aft; and if it be the forward timber of the after-body, and bevells standing as they usually do, it then also follows that its mate or the opposite timber of the frame bevells under; and if we carry out the same order in the bevells that is usually carried out in the futtocks, viz., to reverse them, as we have shown, we may apply the bevel from the left hand, or what is the same thing, take off the opening between the red or blue and white line, and apply it on the right of the board, when it is placed square before us, either above or below a square line, as the bevel may demand. If the white line is without, the bevel is standing from a square the whole

space between the lines and the same amount under ; if as much within a square, these bevels may be transferred to a wider board for use in the yard, and in this case, it will be readily perceived, that we require but one board in the place of two : the same board that shows standing bevels when taken from the left hand, will show under bevels when taken from the right. One of the principal advantages of this mode (is the spacing off the body-plan on but a single side, and reversing the bevel for the opposite timber,) is found in our having but one bevelling board for the fore-body, and another for the after-body ; while by the former method of laying down the bevel in the full size of the timber, we require two boards for each cant body ; another advantage is found in the fact, that the latter is done in less time, and is less liable to mistakes by the workmen. Having but one board with as many sets of bevels parceled out as there are diagonals and sheer-lines, all named in regular order, commencing either above or below, with the bevel against the side of the dead-wood, and then follows in regular order 1st, 2nd, 3rd, 4th and 5th diagonals, and more if required ; next to these we have 1st, 2nd, 3rd, and 4th breadths. Under these several heads are found all the cant bevels of one body ; and it is plain, that if there are but six

cants, there will be but six bevels under each of those heads. The bevel of the heel of the timber against the dead-wood is taken from the half-breadth plan by applying the stock of the bevel by the straight line showing the cant, while the tongue was applied against the side line, which represents the dead-wood. If we have tapered chocks, we must see that the bevel is taken from the moulding-edge, because that being the face of the timber, is the side on which it is applied.

The subject of bevelling the cants being finished, we may find this an appropriate place for giving expositions of the manner of bevelling the square body, although most European architects defer this important, but simple operation, until after the moulds are made. This is evidently wrong ; as it is but too apparent that the lines become dim, and we fail to find that sharpness requisite to take the bevels correctly.

It must be quite clear to the discerning mind that it is the bevelling of the timbers composing the frame of the vessel that gives her shape and form, without which she must of necessity be stamped with a manifest sameness ; the ends must of necessity be what the middle is. But by starting from the dead-flat frame, and causing the one timber to fall without a square, and its

companion of the same frame to fall within, we are enabled to give form or shape to the vessel, and expand, contract, or continue her in any manner we please. The bevels, as a whole, are obtained from different parts of the floor, but principally from the body-plan, and should be taken in all cases before making the moulds, for the reasons already shown. In addition to another fact, viz., that the moulds are of little service without the bevels; for the bevellings of the square body we may prepare two copy boards, which should be left in the loft; they may be of the usual width, eight or nine inches, and long enough to take on all the bevels from the floor; from eight to ten feet will be quite sufficient; the outer edges of these boards must now be placed a parallel distance apart, equal to the distance from the joint of one frame to the joint of the next; and in that position they may be battened on the ends, and a diagonal brace on the lower side, to prevent vibration. Our frame now is supposed to be the exact distance between the two outer edges that the floor timbers are placed apart from face to face, or what is usually termed the room and space, which means neither more nor less than the room between the timbers and the space occupied by the timbers. Commence at the head of the board by drawing a

line square across the board, then take a thin-edged batten, and from the fore-body plan at every sheer-line and diagonal line in their regular order, take the shortest distance from the forward to the next adjoining square frame; this may be regarded as both the standing and under bevellings, (assuming that we are to have but one set of bevels for both timbers.) For example, suppose the forward square frame be Z: the distance from Z to Y is the bevel of Z on any line we may choose to try the opening and the bevel, so with Y; the distance from that frame to X is the bevel of Y, so of W; the distance from that frame to X is the bevel of X, and this may be continued on to the dead-flat frame on the same line on which we began; that is to say, if we began with the first diagonal in the fore-body, continue with that diagonal and in the same body, until we complete the line we were upon; it may not be judicious to take off all the spaces on the batten, before transferring them to the copy-board. The manner of applying them will be found in the following: from and below the square line across both boards, set off these graduations of every timber, remembering the bevels are to be severally named on the board as the timbers are in the body-plan; having the spots on the edge of the board, we may tack a small nail in the

opposite edge of the opposite board, and in the square line; thus it will be perceived, that the nail and the marks on the edge of the opposite board are the whole room and space apart. We now take a thin straight edge, and holding one edge to the nail on one side, and to the first spot below the square line on the other, we mark with a sharp pencil across the board on which the spots were made only; we then drop the straight edge to the next spot; the end at the nail remaining stationary, until all the bevels belonging to this diagonal are taken off. We then square another line across immediately below the bevels of the first diagonal, and commence on the second diagonal in the same manner as the first were taken, giving each set of bevels their proper name as we advance; the sheer-lines are taken in the same manner, all of which follow on in succession, are marked across the one board only, and which will complete the bevels of the square fore-body. We should have enough space left to transfer the fore-body cant bevels, harpen bevels, and knight-head bevels to this same board. We may reverse the order for the after-body; that is, the nail will come on the side on which the bevels have been applied in the square line as before, and taken off and applied in the same manner as the fore-

body, remembering to begin aft, as the after opening belongs to the after frame on this board; also the bevels of the after cants, harpens, and transoms should find a place, inasmuch as a copy of every bevel should be kept until the frame is all worked out. The bevelings of the seats of the floors may be obtained from the sheer-plan, as shown in Plate 8, by applying the stock of the bevel against the line showing the face of the floor, and the tongue extending along the line representing their seats; those bevels need not go on the copy-board, inasmuch as they are not wanted after the floors are worked out.

It was formerly the custom in England, and is still adhered to in some parts of Europe, to take the bevels from the half-breadth plan by setting off the size of the timber each side of the joint of the frame, and taking off the within or without a square the bevel gave; this practice is not only tedious, but it does not give the correct bevel, inasmuch as the lines, even though diagonals, do not cut the frames square from their moulding-edges in all cases, nor can they be so arranged as to accomplish this.

The present practice in England is as follows: to take the opening between the two last square frames for the standing bevel, and the intermediate spaces for the under bevels; that is,

suppose, as we have assumed, Z to be the forward square frame, then from Z to Y would be the standing bevel of Z; its under bevel, or the under bevels of Z, would be obtained by finding the distance to the next square frame forward; the spot for which must be taken from the half-breadth plan, inasmuch as the frame is not swept in; thus for the standing bevels we take the openings from forward in the fore-body, and from aft in the after-body; while for the under bevellings, we begin at the dead-flat frame, and proceed aft and forward, taking the graduations in their regular order, setting off these graduations for the under, below the square line, and those for the standing bevels above it; from these different spots, lines are drawn to the opposite board, as we have shown. This of course contemplates two sets of bevelling-boards; it is the most correct method that has ever yet been adopted. The difference, however, between the manner we have shown is inconsiderable, and would not compensate for the extra work, it can only be perceived at the extremities, and is so small that it is not worthy of notice. The two sets of bevelling-boards referred to, would be distinguished by being marked for opposite sides of the frame; one board for the bevellings of the floors, second futtocks, fourth futtocks, and half top-timber

on one side of the frames of the fore-body, and the other board for the bevels of the first and third futtocks and top-timber of the square frames of the same body. Hence it is quite manifest that four boards would be requisite for the square body, inasmuch as two more boards would be required for the after-body, making four bevelling-boards for the square body; and we may add, that this is the practice to some extent in the United States, both of taking off the bevels and of distributing them on the board; but we think it unnecessary to have more than two bevelling-boards for the square body, commencing with the first diagonal, and following on in succession until we reach the rail-height bevellings. They should be marked on the board from the copy-board in the following manner: first, at the head name the board, that it may be known; then mark a square line across, just below the name, marking this cluster of bevels first diagonal; from this square line set off downward on the left-hand edge of the board, spots about one-quarter of an inch apart. We now apply the bevels in regular succession; the square mark will be the ⊗, and whether in the fore or after-body, we continue on until we reach the highest number or letter, as the case may be, in the alphabet, or in the numbered square body.

Thus we have all the bevels of the square body at the first diagonal together; those on the floor side of the frame are taken from the left hand; and those from the first futtock side of the frame are taken from the right hand. The same may be said of the second and all the remaining diagonals and sheer-lines or breadths.

It has been the custom in the Navy yards to have a bevelling-board, not only for the standing bevels and another for the under bevellings, but one for each class of futtocks, another for the floors, another for the top-timbers, and indeed for every change of name in bevels, another board was deemed necessary. Hence it is not at all difficult to imagine that it took a good share of the time to keep the boards at hand that might be required. In some private yards one set of bevelling-boards are used, as we have described, for the under bevellings, and they are arranged just as we have described another set for the standing bevels in the same order. It is seldom the case, however, that two set of boards are used, unless two sets of bevels are taken.

Before leaving the subject of bevellings, in connection with the square body, we will endeavor to show the manner of making and taking the bevel of the harpens. It will be observed, that the harpens are pieces of plank

scarfed together, and worked out in the form of the bow at one of the sheer-lines, extending from the stem or knight-heads, where they are fastened across the cants to the square frames; they are placed with their upper edges to the sirmarks on the frames, and their extent on the square frames is usually three or four frames; their principal use is to regulate the cants, and give them a landing when raised, inasmuch as they are not a part and parcel of the ship; they are not made very smooth; their top-side, however, should be fair and out of winde at every cant and square frame, in order that the bevel may be applied correctly; the moulds for the harpens are made from the half-breadth plan; few large ships have less than three harpens forward, and three aft. Of late years the custom has prevailed of making a harpen at the load-line of flotation, and, as a consequence, the line has become a sirmark for this express purpose, and is usually sawed in on the corner of one of the timbers of the frame in the direction in which it points across the ship, in order that it may be known from other sirmarks that are put on for other purposes. It is optional with the builder at which of the sheer-lines besides that of the rail that he will place his harpens forward. If the ship has a square stern, he will require none aft at the rail;

there is usually one placed at the first breadth aft, and the one below at the load-line which is continued around the ship. It is not, however, worked out to the shape of the ship farther than the forward and after-pieces, or until it is extended so far that a ribband may be bent the remaining distance midships. The bevels of the harpens are taken in the following manner : apply the stock of the bevel to a level line at the height at which the mould is made in the body-plan. The tongue should then extend downward with the frame, which on the bow will give a standing bevel ; this operation is performed on every cant frame, and on the square frames as far as they extend. It should be observed, that the harpen mould should be made with its hollow edge, or inside to the line in the half-breadth, inasmuch as it extends outside of the moulding-edges of all the frames, and is fastened to the frames to keep them in their places. The mould should also have the station and direction of all the cants and square frames, as far as it extends, marked on it.

We have said that the harpens were secured to the knight-heads forward, this leads us to a consideration of the location and design of those timbers. It will be discovered by the attentive observer, that the forward cants are close together on the stem, and ex-

tend quite high up the same at their heels, notwithstanding their heads may be farther apart than at other parts of the ship ; hence it may be fairly inferred that another arrangement is necessary to give that security to the bow above water that is required ; the knight-heads and hawse-pieces were designed to furnish that security. We have shown in a former chapter that the dead-wood should be of sufficient depth or size to cover the heels of the cants, and we will now add, that the dead-wood forms a continuous line in connection with the keelsons, from the lower side of the lower transom to the lower side of the bow-sprit ; the piece of timber, however, that continues the dead-wood from the bow-sprit down to the stemson, is called the apron ; this piece of timber is bounded on its forward side by the inside of the stem, and when the stem is in two pieces, it is designed to cover the scarf, and extend below that point a sufficient distance to add the necessary strength ; its siding size should be as large as that of the bow-sprit, or within one or two inches of that size, when it can be obtained, for several reasons, which shall follow in their place ; when this cannot be accomplished, we may place a chock on each side to furnish the required size ; the fore and aft size of the apron is determined by what the cants would

measure in the direction of the sides of the apron, added to which should be the thickness of the ceiling. This, it will be observed, would cause the ceiling to butt against the apron, just as the plank outside butts against the stem, with this exception, however, there must be no rabbet. It is seldom that the apron will hold this size, unless the ship is very full, although it should in all ships be carried down at this size as low as the lower deck; below that point the clamps and ceiling may extend over the after side of the apron, and butt in the centre; and the only reason in many cases why the apron does not extend as far aft as we have said that it should extend, is found in the fact that the scantling size of the cants is too large. Our principal reason for advocating a larger apron than the usual size is, that we have discountenanced large stems the fore and aft way, believing them to be injurious to the performance, as well as detrimental to the ship when a cut-water is to be appended, and a part of what we would take off the stem, we would add to the apron; there is no mould required for this timber, the stem mould being quite sufficient. The sides are parallel, and of course stand fore and aft; the after side is assumed to be square from either of the two sides. It is on the sides of the apron

that the knight-heads are placed, extending in some cases from its lowest point, (where it is cut off against the forward cant) to the rail, and often is left a foot or more above the rail; as a consequence, its sides must stand fore and aft, inasmuch as those of the apron does; and faying against the apron, must of necessity stand in line fore and aft, and as the scantling of the cant timbers, as well as all other parts of a ship's frame, is set off on a square, and not on the face of the timber, (unless the timber bevel but little,) it follows that the moulding size of the knight-heads, or their scantling size, should also be measured on a square, and compare in that particular with the adjacent timbers forming the cant frames; from the head of these timbers downward for about two strakes below the head of the stem, the scantling size above this point should be increased both inside and out, this addition should amount to the thickness of the plank forming the bulwarks; the object of this addition is to avoid the ending of the plank in the bed of the bow-sprit, by their butting on the middle of the knight-head and showing their butts, rather than running across the timber.

It must be quite apparent, that if the apron is sided more than the siding size of the stem, that the moulding-edge of

the knight-head must be of different form from that of the inside of the stem. In order to obtain the form of the moulding-edge of the knight-head, we must set off in the half-breadth plan lines parallel with the side-line representing the size of this timber, after knowing how much it will side; there is no objection to its being sided larger than the frame, inasmuch as it affords room for spreading the fastening, and for securing the butts. Having determined upon their thwartship size, we may show them in the half-breadth in the manner described. We have said that chocks were objectionable when the siding size of the apron was not all that we could desire; it is well known that a large amount of fastening finds its way here, and if the holding surface is made up of several pieces, the fastening finds its way into those joints by splitting off the edge of the chocks, and holds less than if in one piece. The sides of the knight-head being thus shown, it will be seen that the moulding edge is formed by the lines running across their sides; these crossings of the sheer and water-lines, if squared up to their corresponding lines in the sheer-plan, will show the form of the moulding-edge; the bevelling-edge is obtained in the same manner; the lines in the half-breadth showing the siding size of the knight-head, may extend to the forward cant, which will cut off the heel of the knight-head whatever the siding size of the cant timber may be shorter than the cant line would give in the half-breadth. We may obtain this ending of the knight-head in the following manner: set off in the half-breadth, the siding size of the forward cant timber, and mark it across the same; it then follows that the knight-head cuts off against this timber; the intersection of this line with the side line may now be squared up to the sheer-plan, which will show not only the length of the knight-head, but that its heel cuts square from the base; it will be observed that the timber will be shorter if the apron is sided more than the stem, inasmuch as the cant of the frame inclines it farther forward at the head than at the heel, and tends to shorten all the timbers that come within the intermediate space. The bevel of the heel is obtained by applying the stock of the bevel against the side line in the half-breadth plan, the heel of which must be forward; we then close the bevel until the tongue ranges out-board and with the side of the cant; this is the bevel of the heel of the knight-head, to be applied from the moulding side or face of the timber, the bevel or angle the other way, having been shown to be at right angles with the base-line; the bevels of the outside, or what is

usually termed the back of this timber, are obtained by applying the stock of the bevel against the line showing the side of the timber, and the tongue out-board to the line at which the bevel is required; or the bevel may be taken by applying a square as in the place of the bevel, the tongue of which must be placed at the intersection of the out-board side of knight-head, with the line upon which the bevel is required; then measure the distance from the square to the moulding-edge of the knight-head; but the most simple, and we think the most appropriate way of obtaining the bevels, is to lay down both edges of the timber, and we have the bevel any where, and may take it off by measuring the distance the out-board edge falls aft of the moulding-edge in the siding size laid down; as a consequence, the knight-head bevels under, just that distance. On very sharp vessels it may be found advantageous to cant the knight-heads, (for the reason,) that a smaller piece of timber will make them. The operation of laying down canted knight-heads is very similar to that of those already described; and when this method is adopted, we should show in the sheer-plan the form of the fore side or bevelling edge of the cant timber, by first marking its size in the half-breadth plan, forward of the joint of the frame; we may then square up

the spots at which this line crosses the several water and sheer-lines, mark in the line by those spots, and we have the ending of the knight-heads in the sheer-plan also; this, however, is not absolutely necessary in the case of canted knight-heads more than fore and aft ones, but it may serve to make the subject more clear by exhibiting it in more than one aspect; the cant of the knight-head may be determined in the half-breadth plan, remembering that the heel must taper, else the head will not come up to the apron; this, it will be observed, would be an objectionable feature, as we have shown, on account of the fastening in the wood-ends of the outside plank; the more cant we have the more taper will of necessity be required, unless the bow be quite straight, at least the length of the knight-head; this renders the operation of laying them down precisely the same as that of the tapered chocks in the cants. We may show both edges in the half-breadth plan with any cant we please; square up the spots at which they intersect the sheer, horizontal ribbands, and water-lines in the sheer-plan; sweep in the curve those spots furnish, and we have their thwartship view in the sheer-plan as though they were cants, which they virtually are; the shape on the face of canted knight-heads is obtained in the same manner

as a cant is, by taking the distance in the half-breadth plan from the middle-line on the line showing their face to the crossing of the several sheer and water-lines; these settings-off are applied in the body-plan the same as though they were cants; in a word, they are cants in all respects, and should so be laid down and bevelled, as also all the hawse timbers that are canted. It is seldom, however, that hawse pieces are laid down in private yards; it is sufficiently convenient to make the mould after the ship is raised and regulated from the harpens; they can then be canted to suit the timber; in arranging the hawse pieces and the knight-heads, we should have reference to the hawse-holes, and not put a long timber in the bow to be cut off. It is quite common in England to locate the hawse-hole either on the draft or on the floor; the bevellings of the heels of the canted hawse piece and knight-head is also obtained as those of the cants; their heels end on the bearding-line, as also do the heels of the cants; all of which may be obtained from the sheer-plan, by placing the stock of the bevel in a vertical line with the timber on the dead-wood, the heel of the bevel up; let the tongue of the bevel turn forward or aft in the direction of the timber; that is to say, if the timber be on the forward side of the frame, let the tongue

be forward, and set to the bearding-line; these bevells should also find a place on the copy as well as the beveling-boards for use.

Having concluded our expositions on the knight-heads and hawse pieces, we shall leave the bow for the present, and follow the course marked for this chapter on the stern of the ship.

Few ships are built for commercial purposes with other than square sterns, although it has been taken for granted that they do not furnish an equal amount of strength with those that are usually termed round sterns. It has generally been assumed that a stern frame was indispensably connected with the square stern; for the present we will only add, that it does not follow that one is consequent upon the other. In defining the boundary line of the stern frame, we are not compelled to follow the stereotyped dogmas of our English cotemporaries, who have found it necessary to have a transom-plan on a separate part of the floor.

The fashion-piece to which the ends of the transoms are attached, may be seen in the half-breadth plan forming a single timber in most cases, and leaving an opening between itself and the after cant, equal to that of those between the cants themselves. Some judgment may be found necessary in striking in the line showing the fashion-

piece, inasmuch as the length and breadth of the transoms are thus determined. As the cant frames continue to cant more as they approach the stern; so also it may be fairly expected that the fashion-piece should cant more than the cant that is immediately forward of it. We have said that the end of the main transom should be seen on the side of the ship, or at least a portion of the same; hence it would seem to follow that this boundary line was unalterably fixed; we have also said that this matter should be attended to when regulating the cants in the half-breadth plan; allowance for only a single timber need be made, although another timber is sometimes added below; the only proper boundary lines of the stern frame are the margin line on the post and the joint of the fashion-piece in the fore and aft direction, and the top of the main transom, and the lower side of the lower transom. It may seem to be an erroneous view taken of the stern frame to exclude the stern post, but a moment's reflection will counteract the influence of that opinion; the stern post will have a place in its present location, even though there were no stern frame.

It will be discovered, that however desirable it may be to spring the ends of the cross-seam, or transom forward, in order to ease the quarter, it cannot be

done without adding to the difficulty in obtaining transoms that will work to the size and bevels required. The transoms are usually placed in the following order: the upper or main transom is usually sided from 12 to 16 inches for ships, one-third of which is kept above the cross-seam for a lodgment for the heels of the counter timbers; the remaining parts below are designed for the reception of the wood-ends of the plank; but inasmuch as a portion is kept above the line demarking the cross-seam, the remaining two thirds are insufficient; hence it follows that another transom has been added immediately below the main transom; the lower transoms are usually sided about 10 to 12 inches, in proportion to the size of the ship, or to the siding size of her frame; they are usually placed from 3 to 4 inches apart: this course is almost universally adopted for durability; they may generally stand with their faces or top-sides parallel to the keel, which, as a consequence, is horizontal, inasmuch as few ships are built with a drag line, or much rake to the post; hence it will at once be seen that little can be gained by canting the transoms, as is sometimes done in the Navy, but for which no good reason can be assigned, their bevellings not being materially altered, while a ship has little or no rake to her stern post.

One other remark, and then we shall proceed to showing the manner of laying them off.

The transoms may be regarded as so many breast hooks placed in the frame, instead of placing them across the inside of the timbers. As the ends of the transoms are bounded by the fashion-piece, it is necessary that the joint of the fashion-piece should be shown in the sheer-plan; it is seldom, however, done on the floor, but always on the draft; their vertical position on the draft is also shown, running horizontal until they intersect with the joint of the fashion-piece. We have already shown that they were bounded on the aft side by the margin line; their intersections with this line may be squared down to the side line of the half-breadth, and a perpendicular also drawn from the back of the main transom or the cross-seam to the same in the half-breadth plan. The section-lines have been described and illustrated in Plate 4. It will be seen that the section-lines come directly across the transoms; they may be adjusted in the half-breadth plan, so as to suit the transoms, and then swept in the sheer-plan by taking the heights above the base of their intersections with the frames in the sheer-plan, as shown on page 137; and were it necessary to furnish a proof for cant frames,(after the lines

have been fully proved before the cants were swept in,)we might find in the section-lines all that we required. It will be seen that those lines running across the transoms and cants, will enable us to obtain spots at any part we may require the same; but apart from this, we already have the section-lines on the floor agreeing with the lines already proved; hence it is only necessary to take off the transoms by taking the distance of their intersection, from the perpendicular in the sheer-plan, to the crossing of the edges of the transoms, as shown in the sheer-plan; let these intersections or crossings be squared down to their corresponding sections in the half-breadth plan; let also the ends, as shown in the sheer-plan, be squared down to their intersection with the joint of the fashion-piece in the half-breadth plan; battens may now be applied to these spots, and lines swept in, which will show the ending as well as the shape of the transoms. It will be observed that the same remark will apply to the bevelling edges that we have made in reference to the upper or moulding side, as transoms should, as a general rule, be counter-moulded. The transoms may now be laid out in the body-plan, simply by striking lines across the after-body side of the plan, at the heights as taken from the

sheer-plan. The length may then be taken square from the middle-line of the half-breadth plan to the intersection of the moulding-edges of the transoms with the fashion-piece; or in other words, take the shortest distance from the middle-line to the intersection of the moulding-edge of all the transoms, with the line showing the moulding-edge of the fashion-piece in the half-breadth; transfer these lengths so taken to the body-plan on the same transoms on which they were taken; a line cutting those lengths will show the actual lengths of the transoms, and the square fashion-piece, or the fore and aft view of the fashion-piece when in its place; the lengths or the settings-off for the fashion-piece, as shown by the mould, is obtained by measuring in the direction of the line showing its siding face in the half-breadth plan; that is to say, lay the batten along the line showing the cant of the fashion-piece, the end from which we measure being placed at the middle-line; then mark the moulding-edges at the point where they strike the fashion-piece; take these settings-off and set off as before in the body-plan. It will be observed that the last settings-off extend beyond the former, and both represent the same timber, and are taken from the same plan; the difference lies just here: the former is what is very properly termed

the square fashion-piece, and the latter the canted fashion-piece; the former line determines the length of the transoms, the latter the length and shape of the fashion-piece; and yet both come together when in their place; this operation is designed for the purpose of proving the accuracy of the work; if there is no error, they will agree; Plate 16 is designed to illustrate the stern frame, and the manner of operation for laying them down and constructing the same. It is sometimes the case that a second fashion-piece is required, to enable us to fill out to the main or first one; this is generally short, extending across three or four of the lower transoms, and as low as the side line; when this is required, we have only to set off its size aft of the main fashion-piece in the half-breadth plan, as high as it is designed to go; it should cut off on the middle of one of the transoms; it may be squared up to the sheer-plan, and from thence taken to the body-plan, or may be taken direct from the half-breadth plan—the results are the same in both cases.

From the nature of horizontal transoms, it will appear evident that they may be readily shown in the three plans, two of which show their edges and fore and aft width only; this arrangement is doubtless readily understood by the reader. The subject of stern frames is



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1. The undersigned hereby certifies that the above information is true and correct to the best of his knowledge and belief, and that he is not aware of any other information that would materially affect the accuracy of the foregoing.

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the 1970s, when they were really "born," the plans, especially their wings and tails, were still in an embryonic stage. The subsequent development of the technology has been restricted to the engine. The subsequent development of the



not as complicated as it would seem to be. English architects have thrown around this part of the ship a labyrinth of mystery that has served to discourage many from daring to grapple with this seemingly complex part. The manner in which the subject has been treated is in itself enough to discourage the beginner; they have assumed, and even averred, that it is necessary to make a transom plan, and then canting the transoms with the sheer, or one at least; and again canting the transoms from a square with the margin line tends to confuse. Now we say that it is not necessary to show them on the floor on more than one plan, that is the half-breadth. We have described them in the sheer and body-plan; it is only, however, for the draft, nor yet is it necessary to sweep in the square fashion-piece on the floor.

We have shown that the line forming the moulding-edge of the transoms extended from the margin-line, or inside of the post, to the line showing the face or moulding-edge of the fashion-piece. It must be quite clear that although the line may be continued to the margin-line, the transoms cannot extend to the same line, for this reason: were there no other, there would be a cavity between the transoms aft against the stern-post; thus it will at once be seen that there would be no

place for fastening the wood-ends, unless they should chance to come on a transom; we may set off in the sheer-plan a distance equal to what the builder may think necessary, both at the cross-seam and at the lower transom, remembering that as the size fore and aft is increased, the breadth is also increased, if it is designed to fill out to the moulding-edge of the transoms. The shape of the ship has some connection with the size, both fore and aft, and thwartships; if the vessel be full close aft, this inner post must not be as large; if lean or quite thin aft, the size should be increased. The inner post, however, may and should extend several inches forward of where it would fail to continue the shape of the transoms; this is for the purpose of boxing the transoms into or over the inner post, or we may do both; that is to say, cut part out of each.

We may sum our remarks up into this, that we may be better understood: first determine the siding size of the inner post; set off half its siding size in the half-breadth from the middle-line; the line will of course be a section-line; square up the crossings at the several transoms to their stations in the sheer-plan; apply a batten to these spots, and we have the fore and aft size of the inner post, without the letting down allowance; we not only have the size,

but the mould, or the line to make it by; strike a line as much forward of this line as we would let the transoms down, and we require no more; the mould for the inner post should extend its whole length, which is from the top of the keel to the lower side of the second transom, numbering the main transom, inasmuch as this transom, and the one below it, come together, they should seat on the post itself when it is placed more inside, and less outside of the ship, for reasons shown on page 103. When this method is adopted, we require the siding size of the post to be larger, as already shown, and we may show half of its siding size in the half-breadth, as described in delineating the inner post. If the stern and inner post have a taper, or is sided more at the head than at the heel, as in all cases it should be, we may square down the heel or the intersection of the margin-line with the base-line; take half the size of the post at that point, and set it off in the half-breadth from the middle-line; likewise at the head in the same manner at the cross-seam set off half the size of the post; strike a line from one to the other. It will be discovered that the crossing of this line and the moulding-edges of the transoms, if squared up to the sheer-plan, will give spots by which to sweep in the seating of the transoms; an

allowance may be made for boxing if required. It would not be expected that the post should fill the whole cavity, if extending any considerable distance forward; it will be observed, however, that a piece might fill up the cavity shown, as it is sometimes the case, that the transoms do not furnish the surplus that the inner post lacks.

Having shown the manner of arranging the transoms, and of obtaining their form or shape in the several plans, we may now show the manner of taking the bevels of the same. The section-line, it will be observed, runs in a parallel direction with the middle-line of the ship, and it must follow that the bevel must be taken and applied in this direction, if taken or applied by section-lines; hence it must be quite apparent that it is a somewhat difficult matter to apply the bevel correctly; for these reasons we would not attempt to take the bevel of the transoms from the sheer-plan, even though the section-lines from which they are formed run in directly a square line from their face; it is, however, only square one way, and to take and apply bevels correctly, we should take them and apply them square all ways, or very nearly so; but this discrepancy is not confined to the section-line; in the water and diagonal lines will be found the same difficulty, if it may be so denominated;

hence we say, instead of bevelling the transoms, counter mould them, or mould them on the lower side ; the shape for the mould of the lower side is obtained in the same manner as that of the upper. The ends of all horizontal transoms is square : we mean by this that the ends coming against the fashion-piece have no bevel, but are cut square from the top-side up and down, and by the end of the mould thwartship ; the bevels of the seats of the transoms are taken from the inner post, as shown in the sheer-plan ; the stock of the bevel being horizontal, and the tongue extending down along the line of inner post, gives the bevel, as we have before remarked.

We cannot attempt to define the size of the inner post, or of other parts of the stern frame, the judgment of the builder must do this. We believe that this is all that should be done ; the man who has not confidence to fill up the sizes proportionate to the size of the vessel, is not qualified to build a ship, let him know how ever so well.

The bevels of the main transom may be taken from the section-lines, or a mould may be made for the lower side ; the mould is preferable. The moulding-edge of the lower side of the main transom is the same for the top-side of the one below, so that nothing is lost by the mould. The starting line, or

as it is sometimes called, the margin-line, from which the bevels commence on the back of the main transom, and which we have denominated the cross-seam, is generally square from the middle-line when its form is not otherwise defined by the model ; there should be a sheer-line terminating here on models generally ; the back of the transom is left square above the cross-seam ; the end of the main transom being shown on the side, cuts off by the first breadth. If that breadth terminates at the cross-seam, and whether it does or not, it is no difficult matter to show the height of the top of the transom in the body-plan, by a line extending across several of the cant frames ; let these be taken off square from the middle-line to their crossing the line just run in for the top of the transom ; these settings-off must now be applied as the same frames in the half-breadth plan, and a batten applied to the spots, which will show the length of the main transom ; a mould should be made by this line, and if the back of the transom has a curve, the mould will show it, but the principal object in having a mould for the main transom, is to give the exact length and bevel of the end, fore and aft ; the mould need extend no farther than the centre or middle-line.

We have shown the manner of laying down the stern frame, assuming

the ship to have a square stern, but it does not follow that this must necessarily be the case. Ships have been built with round sterns, and yet with a stern frame, but the instances are rare indeed, and we do not believe that any private builder would be thus reckless of the cost of this part of the ship.

There are many who suppose that the stern frame is as indispensable to the ship as the masts. We, however, are not of the number; we not only believe that the transomed stern frame can be dispensed with in round-stern ships, but in square sterns also; and we have yet to learn that the ship with a square-stern is not better in every respect without a stern frame than with one, public opinion to the contrary notwithstanding. That the stern frame is strong, cannot be questioned, but the difficulty lies higher, at the connection of the stern above with the stern frame below. In our expositions of the stern frame, we showed a margin of several inches above the cross-seam; the object of this margin is to connect the stern to the stern frame, by boxing in the counter timbers.

We have shown this kind of stern to be the weakest part of this end of the ship, in consequence of the manner of connecting them, and the ending of all the bottom plank at this connection.

No one would be lost in wonder were we to approve of canting the frames all around the stern of a round stern ship. It would be regarded as a kind of matter of course; it is a common practice; but to cant the square stern ship all around, would be regarded as the scheme of some addled theorist. We are not surprised when we hear men talk thus, knowing full well that it is an easy matter to persuade ourselves to the belief of what we want to be true, even though the dictates of common sense pronounce it wrong. We would not be understood to say, that we are lending a preference to square sterns to our ships; we are selecting for no one; we are only endeavoring to show what may be done, viz., a square stern without a stern frame, and with the cant frames extending aft of the quarter to the centre of the stern. It may have been thought that this arrangement was more costly, and, consequently, to be repudiated on this account; but this is not the case. When it is determined to arrange the cants around the entire stern, we should have reference in the half-breadth to the corner or the part at which the fashion-piece is usually located, as shown by Plate 17. The joint of the cant that shows the corner should intersect with the end of the top height line; this would bring one

timber of the frame on the stern, and the other on the side of the ship; this arrangement, it will be understood, must be made in the half-breadth plan. Aft of this frame, on a small ship of 500 to 700 tons, one frame is enough, in addition to the centre counter timbers. If a short timber is required above the cross-seam, it may be put in after the ship is raised; but in no case will more than two frames be required on the stern, if properly arranged, as will appear manifest upon reflection, that those frames with chocks between the timbers cover considerable surface, and at, as well as below the cross-seam, we have all the timber we could desire for the durability of the ship; and it should not be forgotten that we only require enough above the cross-seam to hold the stern plank sufficiently secure; all beyond this, does more harm than good. By adding extra weight, we do not add strength to the ship; and in all cases where there is a half top-timber required on the frames of the stern, they should be of cedar, on account of their being light. After the cants are arranged in the half-breadth plan, we may lay off our section-lines also in the half-breadth plan; it is assumed, however, that before this arrangement is made, the ship has been carried through a sufficiency of proofs on the floor, to furnish data from the

lines from which we may obtain the cross-seam, on the lines shown in the half-breadth plan, and on those shown in the sheer-plan. The first operation then, is to define the boundary line of the stern, which is the cross-seam. We do this in the following manner: as we already partially described in connection with our remarks on Plate 4, on the manner of running in section-lines, for which see page 137, and onward; by thus squaring up the spots where the section-lines cross the cants in the half-breadth to the section-lines in the sheer-plan, we have spots for the thwartship view of the cants in the sheer-plan; but if the section-lines have not been run in the sheer-plan, we should run them in at once, as their endings determine the cross-seam in the following manner: assuming the cross-seam to be square on the aft side with the middle-line, it then follows that all the section-lines that come on this square part, or as far as it runs square, will end in one place, fore and aft-wise; but then again, it does not follow that they will end at the same height; they may rise successively above each other, and will so rise on a well-formed stern. We determine, in the first place, the rake of the stern in the sheer-plan, both at the centre and at the corner; hence it follows, that as our sheer-lines end on the corner, their

ending may be squared down to the half-breadth on the corner and on the centre of the stern each to their respective places in the half-breadth plan; and having the shape of the stern formed in the half-breadth, we have the means of regulating the corner in the sheer-plan, by adding another sheer-line or section-line running only a short distance. It is of more importance to define the corner of the stern when the cauts extend all around than when the ship has a stern frame, because when the stern frame finds a place in the ship, the corner is determined after the ship is raised; this, we are persuaded, is a universal practice in this country; in building square stern merchant ships, it is true, the fashion-piece sometimes runs up to the rail, but this does not show the corner. We have often wondered why our builders did not lay down and take the bevels of the corner counter-timber, inasmuch as they possessed the same facilities for determining its form and bevels that they did of any other timber in the ship, and no one will question the superior advantages of this method over the present mode of making the moulds after the ship is raised. We think the manner of obtaining the form of the corner of the stern in the different positions—that is to say, the side view at its proper rake from the sheer-

plan, and the perpendicular view at its proper rake from the half-breadth plan, has been made plain; and it now only remains for us to furnish the manner of obtaining the half-breadths and perpendicular heights of the stern, when seen horizontally in the body-plan; this is accomplished by taking the heights from the sheer on the several section-lines, (which should also be shown in the body-plan,) and the half-breadths from the half-breadth plan. Having the cross-seam line, shown in the body-plan, we may be able to regulate the line showing the corner or boundary line of the stern, both in the sheer and half-breadth plans, to our entire satisfaction, inasmuch as the ending of all the lines terminate here or partially so; at any rate, there is a brake in every line here, or as is a common expression in the ship-yard, there is an *anchor stock* in the lines here at this boundary line.

It must appear manifest that if the whole quarter were carried out fair with the side and bottom, it only remains to fix the mark around the quarter and buttock for cutting off the stern, and to obtain this is to obtain the cross-seam line on the boundary line of the stern (on the inside of the plank,) or of the timbers before the plank is put on; hence we have shown that the length of the lines is measur-

ed from their ending, and their endings is shown in the following order: first, we have the heights and lengths in the sheer-plan, the lengths and half-breadths on the rake of the stern from the half-breadth plan, and the horizontal and vertical boundary line defined in the body-plan; thus provided, we are fully prepared to carry out the illustrations in relation to the construction of section-lines from the cross-seam to the rail, as shown in Plate 4; and this may all be accomplished on the floor of the loft, even before we make the division for the cants, as we have already shown in our expositions on the floor of the mould loft. It must be quite clear that if the longitudinal lines are all fair, and are proved in their relative fullness or leanness toward each other, that nothing remains to be done but to lay out lines across the ship, or angularly, and they must of necessity make fair frames; hence it is also quite apparent, that this is not a proving process; this being already done, it is merely determining the form shown when in a particular position of certain sections. The principal difficulty, if it may be so termed, after having determined the cross-seam, is in the cant frames crossing each other when shown on the floor; this is unusual in the ordinary cant frames, and would have a tendency to confuse the man who had never

seen them thus spread out before; but it requires but a moment's reflection to discover that the cant frames extending from a position farther forward than they usually are placed on the dead-wood, and in its continuation to the extreme corner of the stern, must overreach another cant frame farther forward than cants much less. In short, the shape of the cants on the ship having no stern frame, are obtained in precisely the same manner, below and forward of the cross-seam, as those of the ship having a stern frame. It is true, they are divided or spaced differently, but this does not affect the manner of doing the work on the floor after thus divided or spaced. In the case of the stern frame, the fashion-piece is the boundary line; in the case of the stern without transoms, the cross-seam is the boundary line. We make this distinction to relieve the mind from the confusion consequent upon the connection with the stern. When the subject is once fixed on the mind in its simplicity, it is not difficult to connect the part above the cross-seam with the operation. We have only to add, that if the cants are taken off by diagonals, as in our former expositions, let them be taken off square first, and carried to the body-plan, to obtain the proper height of the sirmark, as already explained in this chapter; we then take

the settings-off on the cant, as also shown. This operation will furnish us with the form of the cants as far as the cross-seam and no farther, because the diagonals themselves run no higher than the cross-seam; the same operation is performed in obtaining the bevels that would be, were there a stern frame; both of the bevelling edges of the timber on both sides of the frame are shown in the half-breadth, and the frame again taken off, first square, to obtain the height of the sirmark, and then on the cant, and applied on that sirmark; or we may obtain the bevels as explained, by setting off only a distance equal to what would allow the reversing the bevel, as also fully explained in this chapter, and illustrated in Plate 16.

We cannot entertain a doubt but that our expositions are fully understood. We will now follow the subject in its continuance from the cross-seam to the rail; this we shall at once discover cannot be performed by diagonals, nor yet by water-lines, and only by longitudinal or vertical sections; the reason will appear obvious, if we will but reflect that the diagonal ends at the cross-seam; the water-lines are found only below the cross-seam, and heretofore the section-lines have ended at the cross-seam, in Europe and in this country; but we have extended them to the rail, in the full assurance

that they may be rendered of much service in determining mooted points, or seemingly difficult problems about the stern of ships; hence it is plain from what has been shown, that we can only rely upon the vertical or longitudinal section-line for the settings-off necessary to continue the cant frames from the cross-seam to the rail. The sheer-lines we have shown in connection with the illustration of Plate 4, may be continued across the stern, or may be run in as level lines from the corner to the centre of the stern, and if there should not be a sufficient number of sheer-lines to accomplish our purpose, we may run as many lines across the stern, as we please, either horizontal or raised in the centre, as the arch-board or taffrail, but this is or may be thought to be more difficult than the level line, and the level line being all that is requisite, we would recommend them when more is required; these lines across the stern are shown in the sheer-plan, the half-breadth plan, and the body-plan; if they are levelled across, they will be seen to be at right angles with the section-lines, both in the sheer and body-plan, but not in the half-breadth.

The reader will observe that we now commence in the body-plan, by taking the height from the load-line (lest we should make a mistake if we took the

height from the cross-seam) to this level line across the stern on any one of the section-lines, and apply the height so taken to the sheer-plan; we then mark it horizontal or parallel to load-line from the corner to the centre of the stern, which, as will be seen, is a short distance; we next take the shortest distance from a perpendicular line raised temporarily at cross-seam to this line on the centre, and on the corner of the stern, and square those points down both to the centre and corner in the half-breadth plan; from these two points we must extend a curved line across the stern, exhibiting the amount of round the stern would have on a level line—that is to say, without the additional round given by the rise of the arch-board or taffrail, it will now be seen that the section-lines crossing this curved line furnish different lengths from the cross-seam—that is to say, at the centre or first section-line, we shall find the line just run across the stern to be farther aft than at the crossing of the outer or fourth section-line. This will furnish us with data for the continuation of the section-lines in the sheer-plan, by thus squaring up these crossings from the half-breadth to the sheer-line continued across the stern of the sheer-plan. Having these spots furnished, we may proceed in the same manner with the rail, obtaining the spots in the sheer-plan by squaring up the intersection of the sections with the rail in the half-breadth plan; we are thus furnished with three spots for the continuation of the section-line from the cross-seam to the rail; by referring to Plate 4, we shall discover how they will be shown in the sheer-plan. After having the section-lines continued from the cross-seam to the rail, we are prepared to obtain the form of that part of each cant coming on the stern, as shown in Plate 17. This may be done in the following manner: first, we observe the crossing of the cants on the stern by the section-lines in the half-breadth plan, square the spots or crossings up to its corresponding section-line in the sheer-plan; we do this at each section-line the cant may cross: hence it is plain, that we are furnished with spots from the cross-seam to the rail. The casual observer may have supposed that the cant on the stern must of necessity be straight on the stern, running as it does from the cross-seam to the rail, but upon farther reflection, it will be seen that although these lines extending in direct line from the dead-wood to the rail across a part of the stern, yet it cannot be straight, inasmuch as the line drawn parallel with the middle-line and the stern, is only designed to be straight on parallel lines; and we may here add

that if the stern be quite round, and have any considerable twist, it is not straight any where but on the centre. We have given an exposition of the manner of running in the moulding-edges of the cants that in their continuation across the stern supplant the stern frame. If we insert chocks in the cant frames, it is only necessary to show another line in the half-breadth plan, aft of the former line or joint of the frame; and the same course may be pursued that we have just finished; the form of the centre counter timbers are seen in the sheer-plan, and their bevel may be obtained from the half-breadth plan, by showing the siding size, and squaring up the crossings of the section-lines with the bevelling edge to the sheer-plan, and we have the distance the bevelling edge falls within the moulding-edge, and this distance is the bevel in its siding size; the bevelings of the cants, whether the part on the stern, on the quarter, or the buttock are obtained, as we have shown in the present chapter, either by running in the bevelling edges of the timbers in the cant plan, or by taking a distance from the moulding side or face only commensurate with what would avail for reversion; that is to say, the bevels may be obtained by setting off in the half-breadth plan from the line showing the face of the standing timber,

which is the forward timber of the after-body, and the after timber of the fore-body. Now let it be observed, that the distance is determined by the builder; we cannot determine the matter, inasmuch as it is variable, and depends upon the amount of round the line presents to the cants, and we have shown that the more round, the less space is required, see Plate 17.

We have something to add in addition to what has been said in relation to the comparative strength of the stern with a stern frame; the former requires both ribbands and shores to keep it up, while the latter is sustained with the same size and kind of shore that will hold any other frame, showing, that there is intrinsic strength in the frame itself, which the ordinary counter timber does not contain in its connection with the transom.

We have alluded in the present chapter to the side or corner counter timber, and have endeavored to show that the floor of the loft was the proper place for delineating its shape and bevels, we shall now make an effort to show the manner in which this may be performed, presuming that there are many who do not know how to perform this operation; for the length and shape of the mould, we have but to refer our readers to the half-breadth plan, exhibiting the stern in its distended capa-





Figure 1. A 3D plot showing the relationship between the number of nodes (N) and the number of edges (E) for a network. The plot shows a series of curves representing different network topologies, with the number of nodes (N) on the x-axis and the number of edges (E) on the y-axis. The curves show that the number of edges increases rapidly with the number of nodes, particularly for higher-order networks.

city from this or by this plan. The mould may be made as shown in Plate 3, Section 2. If we counter mould the timber, it will be necessary to line forward of the corner in the sheer-plan its siding size ; this new line, as a consequence, must of necessity cross the sheer-lines in the sheer-plan ; let these crossings be squared down to the half-breadth plan, and noted or spotted on the same sheer-lines that they crossed above ; mark in a line by these spots, and we have the bevelling edge of the corner counter timber ; the space between those two lines, it will be observed, is the bevel without a square, provided the after side stood across the ship ; hence it is plain, that we have not all the bevel we require, inasmuch as the aft side does not stand across the ship ; and by the inboard edge of the aft side being farther aft than the outboard edge, the bevel must of necessity be more standing, whence we at once discover that something more must be done ; we may consummate the operation by applying a square to the middle-line at any of the sheer-lines, and determining how much the stern rounds from a square at that point in one foot from the corner ; this added to the bevel obtained for the side, gives all the bevel we require at that spot ; if the stern have a twist, we may apply the square at each spot

in the same manner ; it will also be observed, that the opening on the side between the two lines showing the corner as the moulding, and the forward line as the bevelling edge : in other words, the opening taken for the bevels, must be taken square from the stern, and not in line or parallel with the sheer-lines, inasmuch as the bevel must be applied square, and of course should be so taken ; we sometimes have seen two moulds made, but we deem it unnecessary, inasmuch as the mould made for the corner, can show both the rake of the stern and counter ; this is done by cutting the main or upper piece of the mould off at the knuckle to the bevel, both up and down and thwartship of the counter ; we then make a mould to the counter, and nail them together : the counter mould lapping over the upper piece ; the top of the transom will show the fore and aft line by which to cut off the heel by, and will also furnish the bevels in connection with the mould.

There are several ways of obtaining both the form and bevels of the corner counter timber, but we deem it unnecessary to cumber the pages of this work with more than a sufficiency upon any subject. A few expositions upon the subject of building sterns, and we shall have done with the subject, believing that we have made the mat-

ter clear, and within the reach of all who will pursue our expositions connectedly.

It has been the practice to mould the transoms and fashion-piece larger than the cants, in order that the ceiling might butt against the fashion-piece; this practice in our judgment is decidedly wrong. If the stern frame is of such peculiar construction that it cannot be ventilated but in this way, by excluding the ceiling, and by adding extra weight to the stern frame, it had better be abandoned. In addition to this it does not make a finish, and it must be quite clear to the thinking man that the ceiling cannot extend over the stern frame any considerable distance, inasmuch as the transoms are heavier or larger in the throat than the scantling size of the cants at the same altitude; and being usually made of straight-grained timber, if they should be reduced to this scantling size, the strength would be partially lost. Thus we discover that the stern frame is no great things after all. It does not make the strong or finished job.

The cants around or across the square stern, we have no hesitation in recommending as being far preferable, inasmuch as they equalize the strength, and render their immediate locality more durable by affording greater facilities for ventilation, and at the same

time admit of a continuation of the ceiling either to the lower side of the deck beam, or to meet against the deadwood or inner post in its continuation as high as the head of the stern post.

The subject of making moulds demands our attention in this chapter, and although plain in itself considered, yet in its connection with the distinctive lines necessary for the delineations of the frames or transverse sections of the ship when chocks are introduced, the subject seems to demand more than a passing notice.

There are three kinds of moulds by which a ship's frame may be moulded, only two of which, however, should have any connection with the shipyard; those of the denomination we would exclude are very properly called skeleton moulds, and are better adapted to the live-oak hammocks of the southern sea-board, although (they have been, and still are,) used in our Navy yards for moulding the frames of ships, and such other vessels as are there built.

If an exposition is required of the inconvenience of skeleton moulds, we have but to refer to the floor mould of private yards, which is usually made upon this principle. This mould is commonly made in such a manner that it is capable of containing all the floors of the fore-body on the one side, and



the ends of the beams, the most common method is to secure them against the deck or gunwale by their own weight, and by their own resistance to the pull of the masts and rigging. This method is not very satisfactory, and is not recommended. A better method is to secure the beams to the deck or gunwale by means of a bolt or screw, which is itself considered as a part of the beam's connection with the deck. This method is not only more secure, but it also gives the beams a better support when they are under the strain of the masts and rigging. The beams should also be secured to the deck or gunwale by means of a bolt or screw, which is itself considered as a part of the beam's connection with the deck. This method is not only more secure, but it also gives the beams a better support when they are under the strain of the masts and rigging.

There are two kinds of models which a ship's frame may be modified, and they are both equally important. The first kind is the skeleton model, which is a model of the ship's frame, showing the main parts of the hull, such as the keel, the ribs, the beams, and the deck. The second kind is the floor model, which is a model of the ship's floor, showing the main parts of the hull, such as the keel, the ribs, the beams, and the deck. Both kinds of models are equally important, and both are equally useful. The skeleton model is useful for showing the general shape of the ship's frame, and the floor model is useful for showing the details of the ship's floor. Both kinds of models are equally important, and both are equally useful.

If an expedition is required of the model, the best way of showing the skeleton model, we have but to refer to the floor model of the ship's frame, which is usually made of a far preferable material, and is usually made of a far preferable material. This method is not only more secure, but it also gives the beams a better support when they are under the strain of the masts and rigging. The beams should also be secured to the deck or gunwale by means of a bolt or screw, which is itself considered as a part of the beam's connection with the deck. This method is not only more secure, but it also gives the beams a better support when they are under the strain of the masts and rigging.



Figure 1. Evolution of the electron distribution function $f(v)$ (top) and the electron temperature T_e (bottom) over time t . The distribution function is shown for $t=0, 10, 20$ and the temperature is shown for $t=0, 10, 20$.

those of the after-body on the other. It is formed of battens, and divided into two parts, both of which are assumed to be alike, and each part having for its boundary line the middle-line as a vertical boundary ; the base of the mould is represented in the lower edge of the batten, which is usually just its own width below the base-line of the body-plan ; in other words, the batten bounding or showing the lower side of the mould, has its upper edge to the base-line ; the outward side of the mould has a batten placed with its upper edge to the diagonal, showing the floor heads ; this batten may extend no higher than is required for the reception of the sharpest floor, or it may extend to the middle-line and form the triangle ; the two parts are united by hinges, and may be closed when not in use ; the several diagonal lines and the side lines are also represented by battens, across which the rising of the seats for the dead-wood are marked. When the mould is opened on a floor timber, the frame to which the floor will mould (being marked across the battens) is transferred to the timber by the edges of the battens, and the sirmarks also marked, when the mould is removed, and the first futtock mould is applied to the spots, and the diagonals compared, when the race knife is applied,

and one arm of the floor moulded ; the mould is then reversed, and the opposite arm is also moulded. Where the entire set of moulds are of this complexion, and whole moulds, or such as furnish the entire shape are not used, the space between the spots is carried around the timbers by a sweeping batten.

It must be quite apparent that this manner of moulding a ship's frame is tedious and expensive, inasmuch as several moulders are required, even for what is generally deemed a small company of operatives or workmen. The kind of moulds commonly used are such as show the shape, scantling size, and length of the timbers. There are exceptions in which the scantling size is shown by the marks on the mould, and not by its size ; in such cases the spots showing the size are set off from the moulding edge and swept by the outside of the mould.

It may be well to remark in relation to the floor mould, that its base is sometimes made to show the shape of the floor timber, or its rise above the base ; this mode is preferable, inasmuch as it lightens the mould, which is an item worthy of consideration to the moulder. The battens across the mould are not confined to the number of the diagonals ; there may be others wherever required to bring the spots a

suitable distance apart. It will be observed, that inasmuch as the body-plan shows but one side, or one half for each body, the one half of the mould is marked by lines shown in the body-plan, and the other half is marked by the first, because it is plain that both parts could not be marked from the floor without marking the same side of the mould, and when the mould was opened to show both arms of the floor, the marks would be found on the one half upward, while on the opposite side of the mould the marks would be downward.

It is assumed that the lengths of the futtocks have been properly and previously arranged, and those lengths represented by the diagonals; as a consequence, the only necessity for a double set of moulds would be to show the lengths of the futtocks; this is strictly true when there are no chocks in the frame, or when there is but one line on the floor in the body-plan for each frame; but when (as we have shown that there should be) there are two lines showing the form of the frame, one on each side of the chock, it will become still more apparent that there should be two sets of moulds for each frame—that is to say, the several moulds belonging to the same frame when laid on the floor to their proper places, will show two thicknesses of

moulds as low as the floor heads, and if the edge of one course of moulds thus laid by the line showing the shape of the frames in the body-plan be within the other, and the floors face to dead-flat frame, it will make no difference which body we may be at work in, the fore or after-body, the first and third futtock and top-timber moulds will show their edges outside of the moulds of the other half of the frame, viz., the second and fourth futtock, inasmuch as the under bevelling of the floors, second and fourth futtocks will cause the one set of lines to fall within the other set, just what they are shown to be in the thickness of the chocks, or the standing bevellings of the first futtock, third futtock, and top-timber would cause the one set of lines to fall without the other set, the same as shown in the thickness of the chocks. We have before remarked, that one set of lines may and should be marked with a different color, to distinguish them from the other; this distinction should also characterize the moulds. For example, the first line swept in on the floor being the floor timber, second and fourth futtock, may be marked with lead pencil; hence we say that the floor mould, the second and fourth futtock moulds, should be marked at all the sirmarks or diagonals with lead pencil; the number or letter of the

frame should also be with pencil. On the other hand, the first and third futtocks and top-timbers should be marked with red chalk, both the line on the floor and the moulds; it may be well to observe, the one mould butts at the middle of the other, and the timbers of the frame are arranged in the same manner. The arrangement we have alluded to in this chapter, of equalizing the strength by equally distributing the butts, need not alter the present arrangement; the butts would be taken from the expansion plan, and marked on their respective frames, and the moulds made accordingly; the cant moulds are marked in the same manner where chocks are introduced, and their ending on the side of the dead-wood may be determined by making a sirmark on the mould at or near the heel, a given distance above the baseline, marking the distance on the mould, and then by squaring up on the side of the dead-wood the stations of the cants, as shown on the side line of

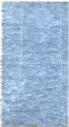
the half-breadth. We may on these lines set up the height of these respective sirmarks, and we have the starting point for laying out the boxing, or as they are sometimes called, the gaines; the heel of the timber itself must determine the size of the box for the reception of the same. From what we have shown, it will be discovered that the moulds are the representatives of the timbers, both in length and shape, and sometimes in size.

In some parts of Europe it is the practice to show the form of a number of frames on the same mould by inscribing their shape; those lines are transferred to the timber by boring holes in the line and through the mould; these are shown on the face of the timber by a second boring, either with gimlet or compasses, and then the form is carried around the timber by the mould; but such expedients would cost more than they would come to in a wooden country like ours.

CHAPTER IX.

Important Rules in Practical Operations—Directions applicable to the successive stages of Advancement in Building—Rules for Planking—Ceiling—Making Spars, &c.

In every *art* there are certain practices, the principles of which are consequent upon the cultivation of operative genius, in connection with the known laws of geometrical science. There are many rules, however, in daily practice that have been transmitted from sire to son, without a knowledge of the principles upon which they are based, or of geometrical science from whence they emanate. Widely different, however, is the radiating scintillations in the horizon of the future, pregnant with the hopeful harbingers of a golden era yet about to dawn. Above, beneath, and around us we see the seeds of change—the germinations of a new life springing into existence. Science no longer secludes herself amid the portals of the cloistered cell of the solitary monk; nor among the impenetrable labyrinths of Egyptian pyramids; nor yet is she hushed into silence by the edicts of Platonic philosophy. Having become a universal benefactor, she sheds her mellowing influences on no secluded walk in life or academic grove, but pours the full tide of her magic sun-beams upon the great thoroughfares of life—on every pathway of humanity, wherever human hope gives birth to human effort. Geometrical science, like the tide-wave that circumnavigates the globe in a lunar day, is destined to sweep over the ocean of mind until it has found a resting-place on every spot of earth that has been sullied by the foot of man—its march is inseparably connected with that of progress. We are persuaded that no attentive observer, possessing a reflective mind, can carelessly canvass the almost startling changes that have taken place in modelling ships, as in other things, within a very few years. The well nigh omnipotent prejudices of the Old World that have held mechanics stationary through the almost interminable lapse of fabulous ages, is working a new leaven that will engender a spirit so potent and so resistless, as to sweep away every vestige of its ancient landmarks; and we anticipate the day







when customs and habits shall be valued, not for their antiquity, but for their use—not for the hoary scalp they wear, but for their utility.

We were involuntarily led to the foregoing reflections upon witnessing the tide of opposition that seemed to be setting against any innovation into the well-known form set down for freighting ships, identified and known by all like the hat-block or the last upon which shoes are made. Happily for the commercial world, there are some who dare think and act for themselves in modelling vessels, the number, however, is by far too limited.

Plate 19 exhibits the lines of a ship designed for the freighting trade between this port and Liverpool; this ship, built in this city, and known and registered as the *Universe*, was launched in March of the present year, and while building was visited by the skeptical and the curious; and it would have been no difficult matter for a practised eye to have read from the observer's glance, the shake of the head, or the shrug of the shoulders, that she was set down by both ship-builders and masters as a ship that would be partially, if not wholly, unmanageable; in a word, that fast sailing and good steering, were entirely out of the question. The ship was finished notwithstanding, and has com-

pleted her first voyage, and is found to roll remarkably easy, steer well, and sail fast, as some ship-masters have abundantly proved, who were sailing in company. We have made the following calculations from her lines, (after adding the thickness of the plank to her moulding size,) which shows her weight, capacity, stability, &c. Her hull and spars, anchors, cables, and tank of 2,000 gallons of water, weighed, when launched, 922 tons 2,100 pounds. This amount of displacement is contained within a draught of 10 feet $1\frac{3}{4}$ inches. The weight of anchors, cables, water, &c., deducted, leaves 840 tons 1,330 pounds, for the weight of the ship; her capacity between that draught and 19 feet, is equal to 1,329 tons 1,640 pounds; her registered tonnage is 1,298. She was originally designed for a two-decked ship, in which case the present plank-sheer would have been her rail. The lines were taken from the tables after being proved on the floor; the water-lines or parallels to the base are furnished as shown on the model; the sixth water-line being an approximation to the proper altitude for what is properly called the line of construction. We may learn the due proportion this line should bear to the depth of the vessel, by referring to page 43; our calculations on the stability were made

from this sixth water-line, it being within 6 inches of its proper height; 18 feet draught of water would have placed the load-line in its most appropriate place, if the original design had been carried out; and the sixth water-line being $17\frac{1}{2}$ feet, we adopted that line as the boundary for our calculations from which to determine the stability of the ship. It will be perceived by referring to Plates 19 and 20, that the centre of effort (the altitude of which determines the stability of the ship) is 2 feet above the sixth water-line, or the constructed line of flotation, and that the centre of displacement is 10 inches above the third water-line. It may be reasonably inferred, without entering into the calculation for the actual centre of gravity of the ship, that the centre of effort is above this point; hence we say, that a vessel has stability if the centre of effort is above the load-line of flotation, unless the vessel be an ocean steamer, or a river steam-boat. This description of vessels should be invariable exceptions to the rule, inasmuch as the centre of gravity of the engines and boilers is often found to be above the line of flotation: thus we discover that it requires no figures to determine that the centre of effort must be above the line of flotation, else the vessel has no stability, and must be ballasted with coal. Not so with sail-

ing vessels; their cargo or ballast is designed to remain permanent, until the termination of the voyage; in addition to the fact, the centre of gravity being below the line of flotation, increases the stability from which is obtained the required leverage of the masts for propulsion. We consider the altitude of the centre of effort in the Universe quite low enough for any sailing vessel, and, indeed, were it 2 feet higher, the ship would be better for the increased altitude. It may be well to observe, that the ship was launched without ballast, with her smaller masts on end, and yet evinced no signs of instability. This is owing to the shape of her floor transversely, in addition to keelsons, of which she had more than an ordinary share; they operated as ballast, enabling her to maintain her upright position. It seems proper to remark in this place, that although the calculation for the centre of effort contemplates not only the principal dimensions, but the contents in its distribution over the immersed portion of the hull and—as a consequence—the shape; so that it will be at once perceived, that however much we may desire to elude the investigating scrutiny of figures, we are destined to be subject to their searching gaze. But still there is one particular in which we may be led into error

by adhering tenaciously to the calculation, without reference directly to the form of the greatest transverse section. We will refer our readers to Plate 5, from which we shall discover that the centre of effort is higher than in the Universe; it does not, however, follow that the ship would have more stability: indeed, she would have less, in consequence partly of the high centre of displacement in connection with the round floor transversely, or the small proportionate amount of flat to the floor from the keel outward; in other words, the long bilge transversely has a tendency to depreciate the stability. The Universe has a very stable transverse section, and although she is a departure from the stereotyped form recognized for freighting ships, yet she is no unworthy specimen of the improvements of this improving age. With regard to the spars of this ship, she is lightly sparred; and it will be seen, by referring to Plate 20, that her centre of propulsion is but 7 feet 10 inches forward of the centre of buoyancy, while the latter point is without doubt farther aft than in any freighting ship in the Liverpool trade at this time—the displacement of the two bodies being about equal. It will be seen that she weighs less than $\frac{1}{4}$ of the load-line displacement, whether taken at the 19 feet or the 17½ feet draught, at which her displace-

ment amounts to 1,929 tons, and her capacity to 1,116 tons. The length between the perpendiculars of the 6th water-line, or $L=175$ feet; the extreme breadth, or $B=37,86$ feet; these multiplied together $= 6625,5$; the area of the 6th water-line, or $W=5537,12$; therefore $5537,12 \div 6625,5 = ,835$; the exponent of the 6th water-line, or $W = ,835 \times L \times B$. Let the height between the rabbet and 6th water-line be $H = 15$ feet, multiplied by $L \times B = 99382,5$; divide this into the whole cubical displacement 66998,75 represented in D ; thus, $66998,75 \div 99382,5 = ,674$, the exponent of the cubical displacement, or $D = ,674 \times L \times B \times H$. The centre of gravity of displacement is 6,52 feet below the 6th water-line; therefore $H = 15$ feet, and 6,52 the distance of the centre of gravity below the 6th water-line; $6,52 \div 15 = ,435 \times H$ below the 6th water-line. Again, the plank, keel, stem, and post displace $\frac{1}{18}$ of the whole cubical displacement; the weight of the ship calculated at $\frac{4}{5}$, $\frac{5}{8}$ are left for the capacity; therefore $66998,75 \times \frac{4}{5} \times \frac{5}{8} = 39289,4$ cubic feet; and as 35,2 cubic feet of sea water are equal to 1 ton weight, $39289,4 \div 35,2 = 1116,1$ tons for the capacity of the ship when loaded to the 6th water-line, or to draught of 17 feet 6 inches.

It may not be out of place here to

furnish some rules for determining, or approximating the additional displacement for the plank on the outside of the immersed part of the vessel. It will be remembered that the lines by which a vessel is built show the inside of the plank; consequently the thickness of the plank must be added in order to determine the displacement, weight, or capacity of the vessel. When planked with oak, an allowance of—

For Ships, $\frac{1}{8}$, $\frac{1}{7}$ or $\frac{1}{6}$	of the displacement may be added.
For Brigs, $\frac{1}{7}$, $\frac{1}{6}$ or $\frac{1}{5}$	" " "
For Schooners, $\frac{1}{6}$, $\frac{1}{5}$ or $\frac{1}{4}$	" " "
For Sloops, $\frac{1}{5}$, $\frac{1}{4}$ or $\frac{1}{3}$	" " "
For Tow-Boats, $\frac{1}{4}$, $\frac{1}{3}$ or $\frac{1}{2}$	" " "
Smaller Vessels, $\frac{1}{3}$, $\frac{1}{2}$ or $\frac{2}{3}$	" " "

If the vessel's frame should be of lighter material than oak, say chestnut, and the bottom planked with pine, the additional displacement for the plank may be set down as follows:

For Ships, $\frac{5}{8}$, $\frac{5}{6}$ or $\frac{5}{4}$
For Brigs, $\frac{5}{6}$, $\frac{5}{4}$ or $\frac{5}{2}$
For Schooners, $\frac{5}{4}$, $\frac{5}{2}$ or $\frac{5}{1}$
For Sloops, $\frac{5}{2}$, $\frac{5}{1}$ or $\frac{5}{1}$
For Tow-Boats, $\frac{5}{1}$, $\frac{5}{1}$ or $\frac{5}{1}$
For Smaller Vessels, $\frac{5}{1}$, $\frac{5}{1}$ or $\frac{5}{1}$

It will be seen that the tables is variable; this is consequent upon the thickness of the plank, and the distance down below the wales; the diminishing strakes may extend; for example, one large ship may be planked with $4\frac{1}{2}$ plank, a second with 4 inch, while a third may have but $3\frac{1}{2}$ inch plank on

her bottom. There is another fact that should not be forgotten in connection with this subject: the strength of Jersey oak plank to the ordinary yellow pine, is as 6:5. Hence it is clear that a ship having 5 inch oak wales to be equally strong, should have 6 inch pine wales. In order to determine the required displacement of a ship to carry a given number of tons, first bring the tons the ship is to carry into cubic feet, add to this the weight of the ship, and from the product subtract the cubical contents of the planking, keel, stem and post; now let D' be the displacement in cubic feet, planking included; D the cubical contents of the bottom, without the plank; N the number of tons the ship is to carry, or the number of cubic feet contained in the amount. $N = \frac{2740}{63} = 35,2$ cubic feet of sea-water contained in a ton, (we, however, will find that 35 feet per ton will, under ordinary circumstances, be quite as well adapted to our calculations, inasmuch as the river water, though salt, is less buoyant, and approximates nearer the latter than the former number.) If the ship is to be built of oak, $\frac{5}{8}$ D' will equal $N \times 35,2$; therefore $D' = \frac{5}{8} \times 35,2 \times N$ the number of cubic feet—the whole cubical displacement with the plank on; from this subtract the planking, say $\frac{1}{8}$, the displacement of the bottom plank excluded, the result will be

$D = D' - \frac{1}{4}$, $D' = \frac{1}{16} = D$ or $D = \frac{1}{16} \times \frac{1}{2} \times 35, 2 \times N$ cubic feet. Should a greater capacity be required from the same dimensions and model, we may elevate the load water-line, and take the cubical contents of the space contained between the former and the contemplated lines of flotation, remembering that the plank should be taken in connection with the contemplated increase of depth.

Assuming that enough has been furnished pertaining to the theory or science of building ships in this chapter, we shall enter at once upon the legitimate subjects pertaining thereto. We have endeavored to bring with us in our delineations on the floor, all the operations of the mould loft save one, viz., the taking off the ship; this should never be neglected, but in all cases the tables of the vessel should be taken off the floor after the whole work is proven. From these tables, we can make a model exactly like the ship, and what is vastly of more importance in case of fire, we may be able from these tables to replace the moulds, even though loft, model, and moulds were burned. A ship-builder would be placed in an awkward position, if after the frame of his ship was half worked out, his model and moulds and loft were burned up, and he had taken no tables from the floor, he would find it a difficult matter to fin-

ish his ship like the original design. Hence we say, the taking off the tables should never be neglected, even until the moulds were made, for this reason: when we begin to make moulds, we find the floor occupied; besides the lines continue to grow dim as we progress in making moulds. In taking off the tables, we should not only take off the lines from square frames, but we should take off the angles of the diagonals from the body-plan, and the angles of the cants from the half-breadth plan, scantling size of the frames, siding size of the stem, keel and post; in a word, we should take off all that may be required to replace our work on the floor, and then it would be no difficult matter to build a second ship like the first.

Among the first operations towards the construction of a ship, is that of laying the keel. This is to the ship what the back-bone is to the human skeleton. The timber composing the keel is usually of white oak; sometimes, however, a kind of timber called sweet gum is used for small vessels that are to be iron-fastened, on account of the salutary influence it exerts on iron, which may be driven into it. Iron bolts are preserved from rust in this kind of timber; this timber is in texture similar to elm, of a reddish color; it is too soft and flexible for the keel

of ships, and will not hold copper better than oak. Much may be said of the size and manner of putting the keel together; its siding size may and should be determined on the model, or when transferring the lines to the floor. A just medium for the siding size of the keel is found in the size of the floors in the throat. With regard to the depth of the keel, the trade and description of the vessel must partially determine this; for large ships the keel cannot be obtained of sufficient depth in the single log; in all cases where it must of necessity be of little depth, the keelson should be of more than ordinary depth. In preparing the keel when in two depths of logs, care should be taken to have the scarphs clear of each other; and we will take occasion here to remark, that the prevailing custom of making the upper nibs of sufficient depth to clear the rabbet, is entirely wrong. It is very generally supposed that the nib of the scarph cannot be made tight unless a stopwater can be inserted at the lower edge of the garboard seam; this is quite unnecessary, and not only so, but weakens the keel; even when the base line is represented in the top of the keel, a three inch nib is all-sufficient, and furnishes more strength than a nib of larger size; when the floors let over the keel, and, as a consequence,

the base line is below the top of the keel an amount equal to what the floors are let down; the nibs may then be less than three inches; the stop-water may then be put in the lower corner of the nib, and the butt of the nib opened with a cut of the cross-cut saw, and caulked with rope yarns solid from the stop-water up. It should be borne in mind that upon the stop-water we must depend; for if the vessel gets ashore, and is hogged, the caulking fails to keep out the water, and the stop-water being at the out edge of the seam, fails to accomplish the purpose for which it was designed, inasmuch as the water works in above. We speak understandingly on this part of the operation, having been more than once engaged in remedying this evil. No matter how many stop-waters are put into the seam of a scarph, the upper one should be in the corner, and that corner should be at farthest half way up the garboard seam of a six inch garboard; in a word, the whole scarph should be caulked, and stop-waters put in at intervals. These remarks on the size of the nib will apply equally well to the scarph of the stem. In a large keel where there are a number of scarphs to be cut, it is a saving of time to make a mould for them; keel scarphs are usually from 5 to 8 feet long, and have what is

termed a hook in the middle of their length. A custom has prevailed, and not without sufficient reason, of having the lower side of the keel shod with a 4, 5 or 6 inch plank in short lengths; the object is mainly to protect the main keel in case the ship gets ashore, in which case she may escape farther damage than would accrue from the loss of one or more pieces of the shoe. The custom has prevailed until within some few years of putting on the shoe after the floor and keelson bolts were all driven and rivetted, and we know of no good reason why the practice should have been even partially abandoned; it is still adhered to in the Navy.

The keel being about to be laid upon blocks sufficiently near each other to prevent sagging between them, we will refer to our remarks made upon the propriety of laying it with a sag in its whole length, on page 118. While the keel is being prepared, the floors are being worked out; the stem and stern frame are also being put together. The union of stem and keel takes place on the top of the keel in ships, but we have seen a number of brigs and schooners on which the scarph was cut on the lower side of the keel; indeed, the practice is quite common in Baltimore. It is adopted to save the expense of a crooked stem, which costs

more than the straight one. The stem with a root to scarph on the keel, we think preferable. The practice is not universally adhered to as in this city, of laying out the scarphs of stern post and keel, and not putting them together before raising. We have seen the keel canted down, and the scarphs put together of both stem and post, and the dead-wood mould applied to determine the rake, and to make a sure fit of the scarphs. We say that the mechanic has but little confidence in his marks, who cannot lay off both the scarph of the stem and post, and know that they will not only fit without a second trial, but that the rake will be as on the floor. It seems to us that nothing can be more simple; the base line runs across the keel or the stem, and is also found on the keel; the frames are also marked on the keel and on the stem; hence it must be clear that to bring the frames to compare in their proper distances apart, and the base line to continue in its course from the keel to the stem, is no difficult matter. We have alluded to the scarph of the stern post; it is comparatively a recent practice to select a piece of timber having a root attached for a stern post similar to that of the stem; the amendment is a wholesome one. The former practice of mortising the heel of the post into the keel, is seldom practised

on ordinary sized vessels. Assuming the keel to be on blocks and set straight transversely, and properly secured with cleets on the cap blocks to prevent its being shifted by any casualty, it will be seen by reference to Plate 15, that the keel is tapered the siding way at the forward end; in other words, the side line is brought nearer the centre on both the stem and keel as they approach the fore foot or the place of union. The practice is quite common of continuing the keel and stem the same size in their whole length on all description of vessels.

Having already treated this subject at some length, we need only say, that if we have tapered the keel on the floor we may transfer the settings-off to the keel, and bring it to its proper size. The dead-wood, it will be remembered, will be compared with the keel, if we, in laying off the cants, have adhered to the tapered side-line, and we will here remark, that inasmuch as there must be a side-line taken for every cant, it is just as easy to take it off from the tapered side-line as from the parallel one. Our remarks apply particularly to sharp vessels; in other words, the tapered keel is more especially designed for sharp vessels, and applies only to the forward end commencing in the usual vicinity of the forward square frame, or at the commencement of the

dead-wood,—the starting point, however, must be consequent upon the sharpness of the vessel. We have designated a point far enough aft for the sharpest vessel. With regard to the top of the keel, it is not absolutely necessary that it should represent the base line. If we have a surplus of timber in the upper log of which the keel is formed, we may strike a base line on the sides of the keel at the proper height, and let the surplus be considered as dead-wood the whole length, reducing the part over which the floors are placed to a definite height, say one or two inches, which will be cut out of the floors, or we may trim off the top of the keel to the base line the length of space covered by floors or square frames. This, however, would be detrimental to the ship, unless we supply its place with a thin piece of dead-wood, which is sometimes done. The object of this is, that in case the keel should be entirely carried away by the vessel getting on shore or otherwise, then this piece of dead-wood is supposed to remain (being in a separate piece) and prevent the ship from sinking. This is, perhaps, a sufficient reason for taking this course with the top of the keel; at any rate the floors should let over the top of the keel, and the line at which they stop on the moulding edge, is the base line on the

keel, and in its continuance up the stem and post, is the same identical line, although custom has called it by another name. We have given it a name as near as may be to the same; we have denominated this line in its continuance the margin line.

It is usual and proper to cut the rabbet on the stem and post before raising them; this may be extended within a few feet of the scarphs from above. For the manner of putting these parts together, see the respective articles. Assuming the keel to be laid at a descent of for a ship $\frac{1}{4}$ of an inch to the foot, and the stem and stern frame to be in their place, or raised on the keel, and the frames marked on the side of the keel, as on the floor of the loft; the faces of the floor timbers may also be placed at those stations, remembering that $\otimes$ is in the after body, and its face should be forward, while those of the fore body should face aft; as a consequence more space will be required between $\otimes$ and A, than between other frames, by the thickness of the chock designed to be put between the floor and first futtock, or the half floor, as the case may be. By the half floor timber, we mean a floor timber half the length of the usual floor, crossing the keel, and of the same moulding size as the regular or full length floor. This practice of placing two sets of

floors across the keel, is of recent origin, and is consequent upon the great difficulty in obtaining first futtocks of sufficient length, size and crook for ships of the largest class; both for steamers and those intended for freighting purposes. This we regard as a welcome improvement, inasmuch as it rids the keel of the range of butts with which it was covered under the old system.

But a few words seem to be necessary in relation to the manner of raising the frames, as being immediately connected with the custom of placing the floors in their upright position across the keel. The manner we have described contemplates a practice that has prevailed for many years in this city, and to which there can be no serious objection, provided the ship has half floors; we allude to the prevailing custom of raising the frames from each side of the ship transversely, or in half frames. When this method is adopted, the floors are placed across the keel to their proper stations, then levelled and let down; by this we mean, that they are so fitted that each floor is in itself not only level, but fits solid on the keel before bolting. We have sometimes seen alternately every other floor bolted to the keel with a single bolt, and the remaining floors left without bolts until the keelson was in its place; we,

however, deem the single bolt insufficient to hold the floor timber and keel securely together, particularly of copper; there should be a bolt in every floor and half floor, (if the vessel has them,) connecting them with the keel independent of the keelson. It does not follow, however, that all the bolts should go through the keel, particularly if the keel is deep; those connecting the half floors to the keel need extend but a short distance into the keel below, a depth equal to that of the floor itself in the throat. While the floors are being bolted, the ribbands may be run a few inches below the floor-head sirmark, and a shore fitted with what is termed a bird-bill over the edge of the ribband to at least every other floor; these shores will regulate the entire floor surface, and are assumed to be sufficiently strong to bear the entire weight of the frames when raised: if not, they should be. The floors being bolted, their throats may be made fair (by running lines directly over the sides of the keel with a stiff batten; after setting up at intervals the proper depth, the keelson being thus prepared) by the adze, may be put in its place, either by skids over the side, or by hoisting them in at the bow or stern. The keelsons should be arranged and fully prepared on the ground, and when this is done, as it should be, it is only ne-

cessary to put them in their place and bolt them. The practice of working the keelsons out a second time in the hold, is wrong; once is enough, but it has become a practice so common to *half* do this part of the work, that it almost invariably requires to be done twice. We mean by this what we say: that in the first place the throats of the floor are inequitable and the keelsons unfair, (although enough labor has been spent to make them correct;) hence it must be quite clear that the keelsons must be fayed after they are inboard; neither do we mean by our remarks, that the edges only are to fay, as is too often the case; and while upon this point, we may add, that it not only costs less, but makes a better job to put a heavy piece of timber in its place but once; and we will further add, that there is no piece of timber that belongs to a ship of any considerable size, but may be made to fit on the first trial. It is true, that it may not be regarded as cheaper in all cases, but we say (and understandingly too) that all keelsons, dead-woods, riders, breast-hooks, &c., may, and indeed should, be made to come to their place the first cut. The great secret in accomplishing this is using a fair but stiff batten and dubbing light; where it is necessary to make a mould, let the side that is to be applied be made to fit; mark the

bevelling spots, and take the bevels with care, and directly square from the face, applying them exactly as taken upon spots that are out of wind; cut to the marks, and the work is performed, time saved, and much heavy lifting avoided, which is more injurious to operatives than the work itself. We will conclude these remarks by adding, that if after our first cut the timber does not fit, we may rest assured there is carelessness somewhere, as the foregoing rules have no exceptions.

It is unnecessary to follow the keelsons farther than show them in their place, as Plate 8 will do. The scarphs should be kept apart as far as possible, and apart from those of the keel; in a word, the best distribution should be made for strength in arranging the scarphs. If the keelson be in two depths it should be securely bolted with through bolts of copper; and where the bolts are long, we would recommend two drifts; the first tier being securely fastened, the upper tier may be principally fastened to the first with iron bolts, reserves being made in the first tier for some copper bolts to go through the whole. Our reasons for using iron in the upper tier of keelsons, may be found in the fact, that iron bolts are stronger, and being above the bilge water that may remain in the vessel, are not subject to the corrosive

influences of rust more than in many other parts where iron is used.

We have shown, in connection with the expositions connected with Plate 8, that the keelsons may and should form a part of the dead-wood; the height of which is determined by the scantling size of the cants at the heel. It may be well to remark here, that the practice of putting in the keelsons before raising the ship, has been continued for years, even when the ship had no half floors, and the heels of all the first futtocks landed on the keel. We deem it wrong, however long continued, inasmuch as the heels of the first futtocks must be reduced smaller than the size of the floor in the throat, or they cannot be forced under the keelson, and after they are in their place they are loose, and too often fit neither above nor below; in a majority of cases the keelsons should be kept out until the ship is raised; and when they are, it usually follows that the cants are kept behind the square frames in consequence of the inability to cut the boxes for their heels, unless the dead-woods are put in and the keelsons over the floors kept out. Further remarks upon the dead-woods and keelsons are unnecessary. It may be assumed that the square frames are being put together, and likewise the after cants, when preparations may be

made for raising the frames with shears. In the meantime the heels of the second futtocks are being laid out and cut off to fit the heads of the floors; the frames, of course, lying with the second futtock side up, it is necessary to perform the same office to the first futtock, when the ship has half floors. If proper care is taken, the butts may be cut exactly, so that scarce a cut will be necessary after the frames are raised. If the ship is large, the first futtocks may, and indeed should be put in their place singly, without the rest of the frame; this may be done whether the ship has half floors or not; and when it is done, the keelsons may be put in before the frames are raised, with the utmost propriety, inasmuch as the course may be faired over the heels of the futtocks, and the keelson made to lay solid over the whole. When the first futtocks are thus raised singly, it is pre-supposed their heads are cut off square from a given angle vertically, and the same from the face longitudinally. We may presume that the frames are ready for raising; and in order to accomplish this part of the work smoothly, we should commence with the after cants, under the heel of each one of which a cleet should be spiked on the dead-wood, and as we shall follow on with the square frames, they may be canted up, and the heels of the futtocks of each frame placed over the floor ribband in its proper berth. In raising the cants, the heel should be entered in the box, and the chain placed on the frame in which to hook the tackle, near two-thirds of the length of the frame from the heel; and when up to its proper height, and the heel in the boxing, the frame may be shored from the ground and stay-lathed from the stern frame. If the cants have chocks between the timbers, the heel of one of the chocks will form a lodgment for the head of the shore; if they have no chocks, a hole may be bored through the timber, and a set bolt inserted in the same. The shears are moved forward as the cants are raised, and each frame is shored from the ground and stay-lathed from its fellow. If the square frames are heavy, and the first futtock appended, it is customary to have a shore in the form of a dog; that is to say, a spruce spar is prepared of suitable length, 10 or 12 feet long, banded at the ends, and a dog-head inserted in each end; the points of which are made thin, and are driven into one of the timbers above and the other below the bilge, sufficiently far to prevent the frame from being racked out of shape, to which it has a tendency, by being subjected to two forces that tend to bring the head and heel of the frame together—the heel on the ribband,

and the head under the influence of the tackle: it is seldom, however, required when the first futtock is not appended to the frame. It is also necessary, when the first futtocks are raised singly, to run a ribband near their heads, and render it secure by supporting it with suitable shores; the square frames are shored and stay-lathed from the adjoining frame, as the cants. It is sometimes the case that the raising of the frames is continued without interruption to the stem, and the forward cants are also raised; the usual mode, however, is to make a separate job of the forward cants. One reason is, the shears are found to be troublesome, and a derrick preferable; a second reason is, want of room to frame them before the square frames are removed, inasmuch as their shape alters so fast that they really appear to be inside out; and the head of the frame requires to be placed next to the keel, and a heel tackle will be needed to raise the heel to its place. The forward cants are not usually raised until one or more tiers of staging is around the ship, and the harpens put on the bow. It is necessary to have one or two diagonal braces either inside or out, spiked on the square frames to counteract their inclination aft, which has been known to cause much mischief by the excess of weight, causing the frames to split

a stay-lath and cant the frames; the cause of the excess of weight is found in the descent of the keel upon which the frames rest.

There is another method of framing and raising, that is deemed by many to be preferable to the manner described. This operation combines the whole frame, and requires a platform somewhat higher than the lower side of the keel, extending the entire length and breadth of the vessel. Upon this platform the frames are put together, the one-half on each side, and the floor in the centre across the keel; after being put together it is raised to make room for another. The operation is commenced at $\odot$ and carried on both forward and aft; the frames are raised with two pair of shears, one pair on each side, standing fore and aft, with a guy from one to the other; the cants are raised in the manner already described. When the latter method is adopted, the cross spawls are put on the frames before raising them. For large ships there should be two sets, and they should be put on the frame at the proper heights for putting on the clamps of the upper and lower deck, and of sufficient strength to sustain the weight of two or three of the beams at the same time. Those spawls are cut to the proper breadths of the frames at those heights as taken from

the floor of the loft, and may be alternately put on every other frame, first above and on the next frame below, or first a spawl for the upper deck, and the next frame one for the lower deck stage. When the frames are raised, as first described, the spawls are put on the frames after the wale stage is around the ship, and then only on every fourth frame. Those fourth frames are regulated first by being regularly spaced on the several ribbands, and set upright by a plumb-line from the centre of the spawl to the centre of the keelson; the intermediate frames are regulated by dividing or spacing the ribbands, and setting the frames forward or aft, and canting as they require; there should be a sufficient number of ribbands, and of sufficient size to hold the vessel firmly to her proper shape. While the spawls are being put on, stage being built, &c., the frames may be sawed down and bolted. We mean by sawing down, running a saw in the butts at the floor, or first futtock heads; should they require one or more cuts, we may have the same guide for this operation that is furnished in framing, viz., the sirmarks or diagonals.

A ship may be said to be regulated when the stem and stern post are found to be plumb, and a line extending from the centre of one to the centre of the other, and at the same time cutting a

plumb-line over the centre keelson, from the centre of all the spawl frames. When thus bound in ribbands, and securely shored with three tier of shores, set up under the ribbands with a spike to prevent their heels from being moved, the ship it may be presumed is fairly regulated, and the original temporary shores may be taken away without detriment. Among the first operations that should be performed immediately after a ship is raised and regulated, is that of boring a hole with an inch and a quarter auger through all the butts of the entire frame; the direction of these holes should be diagonally from corner to corner of the butt, half out of each timber; that is to say, a hole inserted at the moulding-edge on the outside should come through at the bevelling-edge on the inside. The object of these holes is to insert tree-nails that are well-seasoned; they need not, however, be driven only where they are about to be covered, either inside or outside. The tree-nails should be prepared and laid by to season; and as they are wanted, let them be driven as hard as possible. The object of this operation is to obtain strength, which they do in the cheapest and most effectual manner; they do not cost much, and are far preferable to any other kind of dowel that can be used, inasmuch as

there is no chance for the work of the frame at the butt more than elsewhere, which is not the case either with the English mode of dowelling the butt, or of scarphing a chock across the butt.

It may be fairly assumed that the ship is now ready for the various operations of putting on the wales, clamps for the upper and lower decks, plank sheers, rails, stern and head—all of which may be carried on at the same time, with good management. It is seldom, however, that the plank sheers and rail are in the same state of advancement with other parts; not, however, because it may not be done with the same precision and despatch that it can at any subsequent period. Our remarks on sheering will aptly apply here; it is only necessary to determine how the outside shall be finished, whether with flush side or with a projection. We determine the thickness of the outside plank by bending a batten around the $\otimes$ frame on the floor; set off from the moulding-edge the thickness we require; this will determine the height at which the full thickness of the wales are required; and we may run the sheer strake in accordance with the arrangement thus made; it is best, however, to run the first strake as near the sirmarks as may be. For running the deck line, setting up for the inside of the plank, both on the flare of the

bow and on the round of the quarter, see our remarks on sheering, page 140, and onward. An idea may be formed of the usual manner of arranging the clamps, water-ways, bilge strakes, &c., by referring to a longitudinal view of the transverse section of a ship, as shown in Plate 21; the clamps of both decks are being put on, and the beams are often ready before the ship is regulated; hence it follows, that as soon as two or three strakes of clamps are on, squared and planed off, they may be placed where they belong, bolted at the ends into the clamp, and the operation commenced of faying knees; in the meantime the upper sheer strake is being put on, and the upper edge run fair and left standing, inasmuch as it is designed to seam to the lower side of the plank sheer, which has more cant outboard than the round of the beam would give at the end of the same. The beams are sometimes regulated by fairing the lower sides at the centre; but this will not answer a good purpose where the beams show any considerable difference between the size of the middle and ends in the moulding size; they will not make a fair line both below and above. The usual method is to fair the tops of the beams, and if the lower deck beams are in first, they may be shored from the floors along side of the keelson,

and the upper deck beams may be shored fair from those of the lower deck, remembering in both cases that the shores should be kept aside from the centre, that there may be no moving shores to put up stanchions. The most efficient mode of fairing the tops of the beams, is by a ram line extending the entire length of the ship, and hauled taught enough to barely touch the high beams; and we will add, that the ram line is preferable to any other mode of spotting the beams before fairing off their tops; indeed, we have seldom seen a fair deck frame made so by the use of the batten, and we know of no reason why the centre of the deck frame should not be quite as fair as at the side of the ship. The framing of the deck should be arranged on a board, or a draft should be made on which the hatches, mast, partners, &c., should be shown; there should be system in the distribution of the fore and aft framing between the beams; the spaces should be so divided that the carlins that come between the beams may be as near of equal lengths as may be; this can only be done by arranging the fore and aft pieces by curved lines. It will be seen, that if the divisions are made parallel to the centre, the outside berths will be variable. The builder having the least taste will at once discover that it will add to the ap-

pearance of the deck frame, be an advantage to the ship, and an economical distribution of timber, inasmuch as an equality of lengths is a saving of timber.

It is sometimes the case that the knees lap one on the other, and are termed, according to their location, lodge and bosom knees: the lodge knee being fayed first, and being on the same side of all the beams; the bosom knee being placed on the opposite side of the next beam, forming the same berth. The siding size of the knees must be proportionate to the size of the ship and of the deck frame. The knees of the upper deck of a ship from 1000 to 1,200 tons, should not be less than 6 inches, and those of the lower deck from 7 to $7\frac{1}{2}$ inches. If the ship have three decks, the upper deck may be less, 5 to $5\frac{1}{2}$ inches, which would be heavy enough. It is sometimes the case that the beams of all the decks are made larger, and the distance between them somewhat increased, and larger knees used; when this mode is adopted, the knees are abutted in the centre of the berth, and a bosom-piece lapped over both knees, and the bolts driven through the whole from the outside. It will be remembered that two sheer strakes have been run, the first the upper wale, the second the upper string, or the first strake below the plank sheer,

and the space between has been thus far left open ; we will now state the reason why, viz. : to drive the bolts in the knees of the deck frame through the timbers, as before stated, from the outside. There should be a bolt in each timber, and in some cases two ; the iron should correspond in calibre to the siding size of the knee ; $\frac{3}{4}$ iron is heavy enough for 6 inch knees, and $\frac{1}{2}$ per inch for all siding sizes below 6 inch, but knees above 6 inch, should have one-eighth and one-sixteenth added ; this would give for an 8 inch knee $\frac{1}{2}$ iron, or one inch and one-eighth in diameter. Copper is in general used of smaller size, but we know of no reason why it should be, apart from its cost. The proportions we have given will hold good for any sized knee below 10 inch ; but it should be remembered, that bolts over one and a quarter inches in diameter should be driven with a ram, and as this instrument is seldom used, the size of the bolt is reduced, and the number of bolts increased. Those large knees referred to are hanging knees for the lower decks, breast-hooks, &c.

Having extended our general remarks, as far as we intended, on the knees connecting the beams to the sides of the ship, we may add, that a breast-hook is designed to fill up from the clamp to the top of the beam on

the bow, also on the stern of the lower decks, both for the purposes of strength and of making a landing for the deck plank ; and in all the berths on the bow, if the knees are kept down to the clamp, they should be covered with separate pieces to the height of the beams for receiving the deck plank. The fore and aft framing is sometimes let down below the upper surface of the beam ; the principal object in this is to cut less for the reception of the carlin, and, as a consequence, very nearly the same amount of strength is obtained with less timber, and, as a matter of course, less weight. The carlins as used in most of our freight-ing ships are too deep for their breadth ; a carlin $4\frac{1}{2}$ deep by 8 inches broad, is much better in several respects than those of greater depth and less breadth ; first, the broad carlin is better to butt a plank on than a narrow carlin ; again, it cuts less out of the fore and aft piece, and likewise out of the knee ; and in answer to the only objection that can be made, viz., the liability of the spike going through, we say, that 6 inch spikes will hold in yellow pine in a majority of cases until the head of the spike is drawn through the deck plank, and this is all that should be required. We are assuming the deck to be $3\frac{1}{2}$ inches thick and plugged ; this leads us to another consideration : if the 6

inch spikes will hold the plank to the carlins, will not the same spikes hold the plank to the beams? Thus we are led to the conclusion that only one sized spikes should be used for both beams and carlins, and there is no liability to mistakes in getting a beam spike into a carlin. It may be assumed that the knees are all fayed and fastened; the fore and aft pieces all let down; the combings of the hatches let down; and here we would add, that the combings themselves form fore and aft pieces for the reception of the carlins; this is done by making them thicker on the part below the beam, and rabbetting the part above the beam; the carlins may be let down and made to compare with the beams; and we will add, if we desire to have a handsome deck below as well as on the top side, we must plane off the entire deck frame; the ridges left by the adze between the courses can only be removed effectually with the plane. We do not mean by this remark that the edges of the beams are to be run fair from spot to spot, but the entire surface; then if the deck plank are properly planed on the bottom and edges, we may reasonably expect a deck setting close to the beams and carlins, and not unless this course is adopted. The water-ways may be brought on board and fayed.

In our remarks on sheering it was

shown that the sheer of the deck was often much less than that of the outside; hence it follows, that when this is the case, the water-way cannot extend to the bow, and commonly merges into a strake of thick plank forward, usually called sperketting. From 14 to 15 inches is about as deep as the upper deck water-ways are generally made; those of the lower deck are not confined to any breadth or depth, but are commonly made of yellow pine, and sometimes are made of three logs one above the other, and of diminished thickness above. We deem it quite unnecessary to follow up in detail all the smaller items of those plain jobs that come within the range of every man's experience who has worked on a ship. The general outline is all that is needed. It is assumed that the deck frame is fair on both decks, and it is not assuming too much to say that the timbers also are fair; hence we say, that if the water-ways are fair, and have been correctly bevelled, they only require putting in place once, when they will be found to fit to the place they were made for, and may be bolted; the upper edge of the upper deck water-way is designed to seam to the lower side of the plank sheer and moulding their whole lengths, beyond which on the bow the sperketting rises above the deck and continues the sheer, as is

shown on the outside. The plank sheer in its whole width extends no farther than the stanchions are single; the whole frames designed for solid bulwarks make an end of the plank sheer; a moulding, however, is continued around the bow both out and inside, likewise aft, if the ship have poop deck and solid bulwarks. Before the plank sheers can be laid out, the stanchions require to be made fair, and the scantling size reduced to a suitable taper. It is important to know, before tapering the stanchions, the siding way on which side the taper is to be made, else we may be unable to get the plank sheer over the head of the stanchions. The most ready mode of determining this, is to lay a batten along on the strake's edge against the stanchions, marking the centre of each stanchion on the batten, the face side of the bulkhead timbers being also marked; the batten may now be raised up to the head of the stanchions, and those centres transferred to the same; half of the size of the heads may be set off each side of the spots, and the stanchions may be thus reduced to the proper taper, and may be done at the same time that the clamps and strings are being put on. With regard to the sheer of the rail, the rope may be carried around by the sirmarks when the lower sheers are set, or at any subsequent period. It is presumable that the sheer upon the floor is to be the sheer of the ship; if so, we have only to set off the projection outside of the moulding edge of the timbers, or the line showing the same. It will be remembered, that inasmuch as the bow flares, we require more projection there than elsewhere, the amount necessary may be obtained by setting off the thickness of the bulwarks square from the timber, and then measuring on a line parallel to the load-line or base what the bulwarks will give on the bevel; beyond this we require the usual projection on the flare of the bow; one inch to one and a half is sufficient. (It will be observed, that the same projection on the outside all around when measured on the level, will appear to be much smaller on the bow than midships, after the bulwarks are on.) The amount of projection being determined, we have only to set off on the floor this amount outside of the rail-breadth; run in the line, and we have the outside of the rail to which the harpen mould may be applied, and a spiling taken if required; that is to say, if the ship is so finished that the rail extends to the knight-heads. It is sometimes the case that the moulding only extends around the bow as far as the oak bulwarks extend; when this is the case, it is only necessary to take a spiling from that point aft; the

length of the plank determined, and the scarphs arranged on the floor, the width of the rail may be determined by the plank we have, or may be able to obtain, not only the shape of the rail may be determined, but the bevel. It is quite as essential that the shape of the top side of the rail should be laid down, as that of the lower side; and we will add, that the whole rail may and should be worked out and put together on the ground before going on board of the ship. It is presumable that the stanchions have been cut off the length of the tenon above the line designed for the lower side of the rail, and that the stanchions, and indeed the entire side-line, has been moulded fair, with battens both outside and inside. After those lines have been traced, and another line run below on the solid bulwarks, and trimmed out between, we are ready for the rail, which may be brought on board, put together again on the stanchions, and cut down to its destined place, remembering that the rail should have sufficient cant to turn the water outside of the ship, except on the bow, where it cants less, and is set to a line straight across at the knight-heads. The tenons may be cut on the stanchions before the rail is put on, or they may be laid out and all cut at the same time. With regard to the finish forward, the mouldings, when the

timbers extend above the main rail, are worked out to the width which the thickness of the rail would show on the face of the timbers, and bevelled to compare with the cant of the rail on both edges, then being steamed, are bent around. In such cases the ship has no chocks on the bow, but the bulwarks are continued above the main rail, both inside and out, and a smaller rail extends around the forecastle, and is often continued the entire length of the ship, and is known as the hammock or monkey rail. The same remarks are applicable aft, in the arrangements of the poop-deck; the main rail is continued by a moulding the length of the poop deck, and the bulwarks are continued above to the upper rail already alluded to. Thus it will be seen, that when the rail is continued around the bow, it is also continued to the stern without interruption. We unhesitatingly say, that the rail of a ship should be worked out bevelled, and the scarphs fitted before going on board; and it is much easier to fit the work on the ground than on board the ship. The rabbet around the bow on the lower side of the rail, for the reception of the bulwarks, cannot be cut complete before the rail is down to its place without hazard. The scarphs of a rail should be edge-ways; and we deem the key scarph to be preferable to the hook

scarph for rails. The thickness of the rail demands our notice. Commonly a ship of 1000 tons would receive a rail of 5 inches in thickness; the plank sheer the same; but we would make the plank sheer thicker than the rail, for two reasons: first, there is less flare on the bow at the plank sheer than at the rail; and, as a consequence, though the plank sheer be the same size, it will appear to be smaller; second, the strakes grow narrower as we go upward, and consequently make the rail appear heavy; hence we say, that if the rail requires a thickness of 5 inches, we would make the plank sheer $5\frac{1}{4}$ inches thick at least. The width of the rail is variable, from 12 to 15 inches, and even more. We cannot determine any particular kind of finish for the top work of a ship, there is such an endless variety, and all seem to be adapted to the various trades for which they are intended. This, however, is altogether unnecessary; the young builder requires only the general outline. We have confined our remarks to the manner of building ships in this city, which seems to be the standard for nearly all parts of the commercial world. We speak advisedly, having been called on from all parts of Europe for New-York models, both with regard to the form of the hull, and manner of doing work.

These inquiries are not confined to other countries; it is quite common for the ship-builders of New-England and other parts to make a yearly tour, to canvass the improvements in shape, proportions, and finish.

It is presumed that enough has been said about the plank sheers and rail; it may be only necessary to add, that the plank sheer should be laid out the thickness of a rule larger than the stanchion all around. In placing the rule staff for taking the spiling of the plank sheer, care should be taken to see that the edge of the staff is square, and the upper side of the staff is exactly at the height at which the top of the plank sheer is to come, and at the same cant. First take a spiling for the shape of the plank, and then for the stanchions, first by marking their sides; and then taking a large pair of compasses, setting them to a definite size, say they are opened wide enough to reach from the outside of the stanchions to the out edge of the staff, that being on the inside of the stanchions; the compasses may then be applied to every stanchion, first outside and then on the inside; that is to say, apply one point at the outer corner of the stanchion, and the other point in the scribe made for the side; make a prick, and then do the same with the inside; this done on both sides of each stanchion, will

furnish correct data for the holes for the stanchions; the stanchion determines all the scarph that is required for plank sheer; one nib will cut with the side of the stanchion on one side of the plank sheer, and the other nib on the opposite sides both of stanchion and plank sheer. They are commonly put over and trimmed fair on the inside, taken off and the moulding worked, when they are put over the stanchions, but not set down and fastened until the ship is fully salted; sills for the reception of which are put between the timbers about the light water-line, and extend the entire length of the ship; and in order that the salt may run down, part of the chock is removed. The heads of all the timbers are often sawed off below the lower side of the plank sheer, in order that the salt may cover them; both the edge of the outside strake and that of the water-way are presumed to have been trimmed fair, both fore and aft, and thwartships, and at the same time are out of winde. The plank sheer should be bolted edgewise through every stanchion, and have at least two bolts through edgewise between the stanchions to prevent their being split. As it must be quite apparent that there is danger, inasmuch as they have no bearing in the centre, they should also be well-fastened to the strake outside, and the water-way inside. Before we leave the top work, we may show the best manner of putting on the bulwarks on the bow, outside in particular; they are usually put on of oak, and are some 2 inches thick if the bow have any considerable flare and is full; the strakes should not be over 3 inches at the after end; we can only approximate the width, inasmuch as the opening should be equally divided. When an attempt is made to put bulwarks on in 4 to 5 inch strakes, it makes a bad job; they coak off from the timbers, are split, splintered, and broke, and are an eye-sore to a man of taste. We have seen bulwarks put on in parallel widths; take for example the opening at the after part of the bulwarks; divide the same into 12 to 15 strakes, as the case may require; make the strake the same width its whole length, and commencing above putting on the strake under the rail, and continuing down until we shut in aft, and from thence to put on strakes, shutting in on the plank sheer with every strake growing shorter. If this is properly done, it is quite as good as if regularly divided all around, and is quite an item in saving plank; the extra width on the luff of the bow cuts plank to waste. The bulwarks should be narrow from another consideration: the plank is thin, and con-

sequently the shrinkage is greater in proportion to the breadth of the same when the bulwarks are wide. The wales are assumed to be 5 inches thick, we make them usually 7 inches wide; now let us see the proportionate width for 2 inches thick. If $5 : 7 :: 2$ we have $7 \times 2 \div 5 = 2\frac{2}{5}$ inches and nearly a sixteenth; hence it is plain, that we need never be at a loss to know the proportionate width for any thickness of plank that is to be weather proof. We have more than once seen oak bulwarks only 2 inches thick that were about as wide as the wales should have been. We do not set down 7 inches as a suitable width for 5 inch wales; we say that narrow wales would be better, and were showing what is usually done. Yellow pine plank shrinks much less than oak, and it is quite common to plank first class steamships with yellow pine; it is equally durable, and more buoyant, and would make a difference of several inches in her draught of water, even at the same thickness as that of oak; but we have said that it should be of greater thickness to make up the deficiency or loss in strength.

Having extended our general remarks on plank sheer, rail, bulwarks, and wales, as far as we designed, we now go on board, and commence where we left the deck frame. The

hatches may now be framed on both decks. Our remarks in relation to the coamings forming the fore and aft piece, applies to the upper deck principally; the lower deck coamings are usually low, barely enough to turn the water from the hatch. The usual fore and aft piece forms the hatch on the lower deck; there should be a centre strake of deck somewhat wider than the other parts; indeed the width of two strakes would be scarce too wide. This strake should be prepared by being planed both sides; it should also be thicker than the deck, inasmuch as it is designed for the centre strake, and to receive the heels of all the stanchions between decks. The middle of this strake should be laid to the centre; the reason why it should be thicker is to prevent water from running from one side of the ship to the other that may chance to come in the steerage. It is not always the case that it is thicker, nor is it absolutely necessary that it should be so. The stanchions may now be put up between decks, and by referring to Plate 21, we shall discover that they are turned, and that the two decks are confined by a bolt passing through the stanchion and both beams, with a nut on below the lower deck beam. When the stanchions are up between decks, and the edge of the water-way to which the deck is to seam

is made fair, the lower deck frame is ready for the reception of the deck, which is commonly laid straight and in parallel widths not to exceed 6 inches. The upper deck, however, is usually ready for being laid first, and may be so considered when the hatches are framed, partners in their place, bitts in, framing and sole pieces for windlass bitts in their place. The framing for windlass bitts usually consists of thick yellow pine, of considerable width, extending over two berths, covered by a sole piece of equal width, and at least 1 inch thicker than the deck, through which the bitts are mortised. We have seen the windlass bitts of ships that depended wholly upon the knee that layed on the forward side of the bitts; the bitts themselves extending but 2 inches into the sole piece, which was the thickness of the sole piece above that of the deck, having no extra framing below, and there being but one beam to which the knee could be fastened, must depend upon the sole piece principally for support; and yet such ships have been, and doubtless still are, insured as first class ships. The fore and main partners are often formed of mahogany, of from 9 to 12 inches thick, in 2 to 3 widths, and extending from the fore and main hatch to the respective beams aft, and bolted securely to the same, also connected

together with bolts edgewise. It seems to be necessary to have a very considerable thickness to the partners, inasmuch as the masts, bitts, pumps, &c. going through leave but little solidity without considerable thickness. Assuming the water-way seam to be fair, we shall proceed to delineate the manner of laying the upper deck, the beauty of which consists more in its fair, handsomely curved seams, and proportionate taper, than in the quality of the plank. White pine is preferable to other kinds of timber for the decks of merchant vessels. Narrow strakes make the best deck, for two reasons: first, there is less shrinkage to the narrow than to the wide plank, and, as a consequence, the deck will remain tight longer; the second reason is found in the firmness or adherence to the beams of the narrow over that of the wide deck, where by some mistaken freak, the deck is caulked hard. The width of the plank should bear the same proportion at different parts that the deck does; that is to say, if the deck at the stern is but three quarters of the width of the deck midships, the plank should be the same; in other words, if the plank be 5 inches wide midships, $3\frac{1}{2}$ would be the width aft, inasmuch as $3\frac{1}{2}$ inches are three-fourths of 5 inches. Again, suppose the width of the deck at the fore hatch is $\frac{1}{2}$ of the whole width, does it not fol-

low that the plank should be the same? and that if the plank were 5 inches wide midships, it would be but $4\frac{1}{2}$ at the fore hatch. We must determine how many strakes the deck will require at 5 inches. Suppose the deck to be from water-way to water-way 33 feet 4 inches wide, which at 5 inches would require 80 strakes, only half of which we require on each side, now it is plain that the centre seam is straight, and that the curve gradually increases on every strake as we proceed towards the water-way, and we shall discover that the water-way seam has more curve than any other seam in the deck; this symmetry is brought about by the taper of the plank, as we shall see. A batten may be prepared, and the half width of the deck taken at about 5 places: 1. at the widest part, and 2. settings-off forward, and an equal number aft, and we have the problem for solution at once at each of the settings-off. First, if the midship breadth, being 16 feet 8 inches, (which is the half of 33 feet 4,) gives 5 inches in 40 strakes, what will the half-breadth of the next setting-off give? and we may in this manner obtain the widths at the several settings-off. We cannot adapt the taper to the bow, and it is not necessary to take a setting-off forward of the foremast. There are other modes doubtless equally as good for diminish-

ing a deck, one of which we shall give: divide the space marked on a batten between the half width taken at the stern, and the half width taken midships, into as many portions as there are strakes in half of the deck, say 20, and number the parts as widths in inches and eighths; for example, as we have shown, let the width at the after beam be $3\frac{1}{2}$; the first of those spots should be marked $3\frac{1}{2}$ and $\frac{1}{16}$; the second $3\frac{1}{2}$; the third $3\frac{1}{2}$ and $\frac{1}{8}$; the fourth 4 inches, and so on in like manner we advance 20 sixteenths from mark to mark, and reach the full width, viz., 5 inches. It will be understood that we are arranging to work out a strake the same width that the whole deck is to be, and then this strake is arranged and regulated with large spikes in the following manner: take a small batten and make a scale for an opening of say 7 strakes, and in order to obtain this we have but to add the 7 widths together, or multiply the width of the after end by 7, and we have $26\frac{1}{2}$ inches; we now measure $26\frac{1}{2}$ inches from the square end of a small batten, and divide the space between the $26\frac{1}{2}$ inch mark and 35 inches (this being the whole width of 7 strakes 5 inches wide) into 7 equal parts, marking each spot as follows: the first spot $3\frac{1}{2}$ inches; the second $3\frac{1}{2}$ and $\frac{1}{8}$ inches; the third 4 inches; the fourth $4\frac{1}{2}$ and $\frac{1}{8}$ inches;

the fifth $4\frac{1}{2}$; the sixth $4\frac{1}{2}$ and $\frac{1}{4}$; the seventh $4\frac{1}{2}$; the eighth $5\frac{1}{4}$. We thus discover that we must either go into fractions not found on the carpenter's rule, or divide the space by sixteenths, inasmuch as seven times one-eighth and one sixteenth make one inch one quarter and one-sixteenth, which is $\frac{1}{4}$ too much; this, however, makes no difference, as we can make the opening $\frac{1}{4}$ of the space between $5\frac{1}{4}$ and $4\frac{1}{2}$ less than the spot at $5\frac{1}{4}$ calls for, and we have what we want. The reason is obvious; there are $\frac{1}{4}$ difference between the width $4\frac{1}{2}$ and $5\frac{1}{4}$; consequently one-third off leaves just what we want, viz., 5 inches. We have selected an odd number of strakes for two reasons: first, that we might make the most intricate case of division that would be at all likely to occur perfectly plain; our second reason was, that we might have the shutters in the deck properly distributed; and we would add, that every fourth strake should be a shutter if we would have a tight deck. Our batten being prepared, we must apply it aft, the square end against the water-way, and tack the strake at the first spot; here we discover the strake is $3\frac{1}{2}$ inches wide, and that 7 strakes of the same width will fill up the opening, because 7 times $3\frac{1}{2}$ make $26\frac{1}{2}$ inches, and that is the distance of the first mark from the end of the batten; the

after end of the plank being tacked, we shift the batten forward, and apply it to the opening, where we find the plank corresponds in width with that called for by the next spot on the batten; that is to say, where we find the plank to be $3\frac{1}{2}$ and $\frac{1}{4}$ inches wide, there we set the strake to the opening found at the second spot; thus we continue the operation until the whole strake is set not only to the widest place on the strake, viz., 5 inches, but the whole distance forward as far as the deck was first divided at the fore hatch, from thence the strake may continue fair to the sperketting. If the strake thus set is fair, or shows a fair outboard edge, we may readily conclude that our divisions are correct, and may run off any irregular swell the inboard edge may show; the strake being about what we want, may be fastened. Due attention to the manner of fastening is quite essential; for a white pine deck of not more than 5 inches wide, one spike in each beam and carlin is enough, except at the butts; they should be crossed alternately, first on one edge of the plank; the next on the opposite edge. The same arrangement should be made with the beams and carlins; the spike should be one-third of the width of the plank from the edge; its length must be determined by the thickness of the plank. Having fastened

our first strake, we may use the same settings-off or scale for another opening of seven strakes inboard from the first; this strake, it will be perceived, forms less curvature than the first, and each strake must of necessity continue to straighten as we approach the centre; this strake being worked to the width called for, and the opening set by the batten, showing at the same time a fair seam or edge, may also be fastened. We now have one-half or one side of the deck divided into three principal openings, two of which are equal. This arrangement, however, is not arbitrary; the last strake may interfere with the hatches, as it no doubt would. We may divide again, and take a fourth strake from the first, and having the strake and opening to agree, the strake may be fastened, and another made to seam to it on each side; so of the first, this will leave an opening of one strake, which is termed the shutter; the outside berth or opening may be divided by having a strake in the centre, and to that centre strake another on each side, which will (by adding another strake to seam to the water-way) leave the remainder of the deck in shutters; those openings may be filled by bringing the plank on board with only one edge planed, and worked out to the size of the opening on deck, or the size of the opening

may be taken on a batten and carried to the plank. The shutter should be driven in tight, but it will not answer to make the plank more than one-sixteenth larger than the opening, else we will be liable to shatter the plank in driving down. It is a common practice to chamfer the shutter; this is wrong, the upper edge of the plank forming the opening should be chamfered, if any; the seam below should be as tight as possible.

We have said that the divisions of the openings were not arbitrary; we will also add, that the precise manner of dividing is not arbitrary. We have only shown the principle; the manner of dividing may be left with the practitioner. We may take such number of strakes as shall make an even number of eighths, or sixteenths, or thirty-seconds of an inch, or we may adopt the decimal mode, as shown on page 3; the principle is the same; where the taper is more gradual the marks or settings-off on the batten will be closer together than where the openings increase or diminish faster; but again, the same gradation, in fact the same scale, applies equally to a more or less gradual taper; that is to say, in adapting our scale to an opening to be filled with a given number of strakes, having reached the largest part of the opening, and the opening begins to grow smaller,

but in a diminished or increased ratio, it makes no difference in the scale, because the opening is to be filled with the same number of strakes as the first. The same principle applies to the division of the batten for planking, to which, however, less attention is paid, because it is not necessary that the plank on the outside should be of equal width, but it is very important that the deck should be very nearly equal in the width of the strakes. We may adopt the same mode in the strings, taking the opening forward between the strakes under the plank-sheer and the upper wale, assuming that it was in accordance with this width, or with an equal division of the strakes that the first strake was put on; assuming the opening to be one of six strakes, or that six strakes of the same width as the upper one will fill the opening; suppose the opening forward to be 30 inches, and midships to be 33 inches, is it not plain that the strakes must be 5 inches wide, inasmuch as 6 times 5 are 30? and is it not also quite as clear that the width midships must be 5½ inches, inasmuch as 6 times 5½ are equal to 33 inches? Thus we discover that on a batten 33 inches long, we may make a scale by which to determine the widths of the strings, provided the opening be as we have assumed it to be; hence it is plain, that if an open-

ing of 30 inches requires 6 strakes 5 inches wide, and 33 inches also requires 6 strakes of 5½ wide, it must be equally clear that if the space between the 30 and the 33 inch mark be equally divided into 4 parts, that each of the marks will represent the width required to fill the opening in 6 strakes at any place where the opening corresponds with the mark. For example, we make the first mark from the square end 30 inches; at 30½ inches we mark the batten 5½; at the second, 1 or 11 inches we mark 5½; at the third, 2 or 21 inches we mark 5½; at the fourth, 3 or 31 inches we mark 5½ inches; now does it not appear plain, that the six-eighths of space between the spots represent the six strakes? and it would make no difference whether it were sixteenths, eighths, or quarters of the inch of space between the spots farther than this. The closer the spots on the batten, the nearer will be the settings-off or the widths furnished to line the plank by; if, however, the spots or widths are given within 5 feet of each other, it is near enough. We may present this subject in another form, to which we have referred; the widths may be expressed in decimal parts of the foot; for example: 5 inches equal .42, and 5½ equal .43; so with 5½ which equal .44; in like manner 5¾ equal .45; and 5½ correspond with

.46; thus we discover that the decimal parts of the foot express all we require, and furnish a universal system by which all may work: if we require the sixteenth of an inch expressed in decimals, we may have it also thus, 005. We would be glad if this system were universal in the ship-yard as well as on the tables of displacement, what an almost endless number of mistakes might be avoided! One man expresses, for example, five inches and three quarters, $5\frac{3}{4}$; another will set it down 5 $\frac{1}{2}$; a third 5 $\frac{1}{4}$; a fourth would call the first example 5 feet 6 inches; hence it must be clear to the thinking man that all mechanics, particularly those of the same business, should express measurements in the same manner. What now seems perfectly legible to one man, is hieroglyphics to another; and we unhesitatingly say, that every mechanic should fully understand the decimal expressions as shown on page 3.

It may not be necessary to carry our expositions farther, believing that they will be readily understood by the thinking reader. The same rules apply equally well to any part of the ship, but need not be applied on the outside. Indeed they cannot be applied with any considerable advantage until the bilge is reached from below, and then we may not find it advisable to be confined to equal divisions from the graded scale.

It is not important that each strake should be exactly of the same width below the wales; indeed it adds to the symmetry of the whole structure to have the strakes freed from that continued sameness that is consequent upon having a great many strakes of the same width. The strings appear to advantage equally divided, as also do from 10 to 14 strakes of the wales, (the number of strakes of wales is variable, according to the shape and size of the ship,) but below these the diminishing strakes and the bottom plank may vary in width to advantage. The true principle in planking and ceiling may be shown in the following exposition: suppose a spot is made at the wood ends, both forward and aft the height any named strake is required to come, a spot may also be made on one of the midship frames at which the same strake is required to come. We will now assume that a ram line be drawn straight from the wood ends forward to the same aft, and made fast at each spot; we will next suppose we can take a range that will bring the line and the spot made midship in the direction of each other; while the eye thus cuts the spot midship, let others be made at convenient distances for lining from one to the other, both forward and aft; and having the line stricken around the side or bottom, we

have the direction the strake should run; it matters not whether the strake points high or low: whether the strake be on the bottom or on the side. It may be thought that because of the cross seam preventing the rise of the after end, the rule would be useless; but this makes no difference; the strake comes outboard on the transom in the same ratio that the forward end rises. This we say is the true principle upon which the direction of the plank both inside and outside should run. If the young beginner is desirous to have this mode made familiar to his eye, he may apply a long straight edge on the upper edge of any strake he may select on the bottom at say one-third of its length from forward or aft; let the straight edge be long, and for convenience it may be placed with its upper edge at the seam, and the outer end be left moveable, in order that it may be raised or lowered until the eye and the edge of the strake blend into each other; he will then readily discover any discrepancy in the direction—in other words, a swell or a hollow will be readily detected. Before moving the straight edge, let another be placed one-third from aft, both at the seam and out of wind with the first; the sight being now taken from aft, we shall see how the strake forward accords with the principle laid down. We repeat that it is

not necessary either to run the line or to apply the straight edge. We have described them as being the best modes of illustrating the subject. With regard to the ceiling, it does not follow that the strakes would run as they do outside. We may run them in the direction of the water-lines if we please, with the ends down and the middle up, and still the principle is not affected; or we may keep the ends higher than those on the outside. We may readily make the application of our first exposition with the same line on the inside, and set the bilge strake in this manner. The manner of arranging the keelsons, bilge strakes, and ceiling, is not arbitrary. Plate 21 exhibits a very efficient mode of adding strength to a ship in the distribution of the keelsons, thick strakes, &c. It may now be necessary to return to the clamps, both between decks and in the lower hold. We assumed that it was only necessary to run two or three strakes before putting the beams across; we may, at a suitable time after the deck is laid, run the remaining strakes. There may be some objections in the minds of many to this course, inasmuch as the tree-nails in the wales being driven, must of necessity be cut off and wedged on the timbers, that the tree-nails should go through the clamps. To obviate this the tree-nails

may be left out of those strakes, particularly opposite the lower deck clamps; it is quite common, however, to commence below, or at the bilge to ceil, and follow up with the clamps. We think this mode objectionable, inasmuch as it keeps the lower deck behind, or in a less forward state of advancement than the upper deck, which should not be the case under ordinary circumstances.

With regard to the strength of tree-nails, there can be no question of their adding a great amount of strength to a ship; but where the plank is heavy and the timbers light, we prefer bolts, particularly on the inside of a ship, where the corrosive influence of rust is less than on the outside. We say that the tree-nails may be driven harder through the wale and timber than if they extended through the clamp, and being wedged on the timbers, are equally as good as if they extended through; and, as a consequence, kept a bolt out of the lower deck clamps, where the outside plank is usually thinner than on the outside of those above. There should be system in fastening ships, and indeed all kinds of vessels, and we have been often surprised to see the loose and random manner in which fastening was put in ships. Not a bolt or spike should be driven in the ceiling or clamps (where the tree-nails are

designed to come through) more than is actually necessary to hold the plank to the timbers, until all the through fastening is in from the outside; and we have known ships that were thus systematically fastened to be set down as slightly so, because the fastening was not all put in when the plank was put on.

With regard to the amount of fastening that ships require, we may add, that ships having two or more decks require 40 pounds of iron and copper fastening for every ton of *displacement*. This, if properly distributed, will square fasten the ship; that is to say, it will allow 2 bolts or spikes in every timber where there are no tree-nails, with an abundance for frame bolts, thick strakes, keelsons, breast-hooks, deck frames, hanging knees, stanchions; in a word, for all the metal fastening required in a ship.

We deem it quite unnecessary to protract our remarks on the manner of construction in the present chapter, nor would we underrate the ability of those who may feel themselves qualified to build a ship. The exposition of some important rules that have been illustrated but not explained, may suffice for this chapter.

The first we shall notice is found on Plate 8, Fig. 1. This represents one of the readiest modes of obtaining the

sweep of a beam-mould or arch-board. It will be discovered, that like all other sweeps it has a base line ; this line is straight, and extends the entire length the mould is required to be. The centre of this length is obtained, at which point a perpendicular is raised, and the required round set up, a quarter circle being swept from the perpendicular to the base, is divided into any convenient number of parts. The diagram shows 5 equal parts each side of the centre. As will be seen, the quarter circle is also divided into 5 equal parts, both on the base and on the circle, and lines drawn from one to the other ; the angle is then taken with a protractor or bevel in the direction of the division and at the corresponding lines on the base, that will bring their inclination from the centre of the base, as shown in the dotted lines ; the several heights of the dotted lines in the quarter circle may next be taken, and applied on those inclined lines, and a batten bent to the spots ; while the batten is thus bent, we may divide the curve shown by its edge into equal parts ; we then remove the batten without marking it, and draw lines from the divisions on the base to the last divided spots, and set up the heights on those lines ; again bend the batten to the last spots, and mark by the batten the curve, which is the true curva-

ture of a circle. It will be perceived, that inasmuch as the quarter circle is divided into equal parts, it is necessary to divide the large circle in the same manner ; and that the segment of the large circle cannot be divided before it is made ; and for the purpose of obtaining an approximation, we have shown the angles ; a square line, however, would doubtless answer the same purpose. Fig. 2 shows another mode of obtaining the same, but is better adapted to sweeps that have more round in an equal length than Fig. 1. For example : to an arched hog frame on a steamboat, Fig. 2 would be better adapted for showing its periphery than Fig. 1 ; it is quite simple, and is made, as will be seen, by first striking a base, then raising a perpendicular, and setting up the height of the required arch ; this height divided into any number of parts, a sufficient number to sweep by is all that is required ; from the upper spot strike a line to the terminus, from which we raise another perpendicular, and again divide as before. Lines stricken to all those settings-off, and repeated on the opposite side, will furnish intersections on their corresponding lines, as shown in Fig. 2, and are the spots required for the circumference of the circle. We have also shown, on Plate 11, another mode of obtaining the same

curve, usually used for beam moulds; it is formed by the base perpendicular and equal division principle; it is simple in its construction, and requires, we think, only to be attentively examined, as shown by the diagram, to be readily understood. Fig. 1, Plate 18, is designed to describe the arc of a circle that shall contain any number of degrees; the operation being performed without compasses, and in one particular like the former examples, without finding the centre of the circle: place two rulers forming an angle, as shown in the diagram; let the angle be equal to the supplement of half the given number of degrees. (The supplement of an arc or angle is what must be added to it in order to make a semicircle or 180 degrees,) and fix them as shown, their connection above being the altitude we require, or their upper edges forming the angle we desire with the base. Place two pins at the extremities of the given chord at the termination of the sweep, and hold a pencil in the socket formed by the union of the rulers above, or on their upper edge; then move the edges of this instrument against the pins, and the pencil will describe the arch required. Suppose it is required to describe an arch of 50 degrees on a chord of given length, or on a base of given length, (the chord is the straight line

which joins the two extremities of the arc of a curve, so called from the resemblance which the arc and the chord together have to a bow and its string, the chord representing the string;) subtract 25 degrees (which is half the given angle) from 180, and the difference, 155 degrees, will be the supplement; then form an angle of 155 degrees with two rulers, and proceed as shown in the diagram. Fig. 2, Plate 18, shows the proportionate taper of spars. We have assumed that either of the straight boundary lines were the base, and have dropped the perpendiculars from the circle to both lines, showing that the results are the same. This sweep, used by spar-makers, (when there were fewer spars made than at the present time,) furnished the proportionate taper of all sized spars. But the practice of drawing a sweep for a spar of any description, has long since grown obsolete; it is only necessary to know the length and diameter, and the spar-maker will at once mark with a piece of chalk these same proportions on his rule within the half diameter of the spar in its largest place. Suppose the spar to be made be a yard 75 feet long and 18 inches in the slings, or 4 feet of length for every inch of diameter, which is recognized as the proportion for smaller spars in the mercantile marine,

18½ would be the proper diameter for this yard; but this is about as near as spar-makers generally come to any standard of proportions. Another example may serve to show how near proportions are carried out in spar-making: the ends of lower yards are set down at half an inch less than half the size of the slings, but it is quite common to find them both above and below this medium. We have long since come to this conclusion from close observation, that proportions for yards were far from being good. Doubtless the experience of a long life of sea-service would scarcely witness the carrying away of a yard in any other part than the slings; this, it seems to us, should teach the thinking man that they are too small in the slings. The manifest error in the same rule when applied to lower masts, becomes apparent, even to the casual observer. A lower mast, of 85 feet, would be made not less than 32 inches in the partners, which would differ but little from one inch of diameter for every 2½ feet of length. There never has been any system brought forward that would universally apply to all descriptions of spars; we cannot, however, suppose that the proportions now used for lower, top-sail, and top-gallant yards, are free from manifest discrepancies. To illustrate the proportions

now in use, and in order that we may be clearly and fully understood, we will add, that it is not our purpose to furnish in this chapter any proportions for spars as connected with the vessels for which they are intended, but to analyze the manner of proportioning the one part of a spar to the other after the dimensions are given; in a word, we have at present nothing to say to the builder who furnishes the dimensions of the spars, but to the spar-maker who makes them; (they, however, are often confined to glaring errors and manifest discrepancies by the masters of vessels, who suppose they know about all.) We will compare the proportions given at the several settings-off of a yard with those we shall propose, and draw such inferences as the subject may demand. Assuming a lower yard to be 80 feet long, and 20 inches in the slings, strike a centre line on the spar, (after spotting it to prevent its rolling,) middle it, and divide each half length into 4 equal parts, which, with the middle and end, will make 5 spots or settings-off. The ordinary settings-off or sizes to be applied at the several spots each side of the centre line would be as follows: in the centre 10 inches; at the first setting-off from the centre on each end, 9½; at the second setting-off or spot, 8½ inches; at the third, 7 inches; and

the 1990s, the number of people with a mental health problem has increased by 50% (Mental Health Foundation 1999).

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The purpose of this paper is to review the current state of mental health services in the UK, and to discuss the challenges facing the sector.

The paper is organized as follows. First, we discuss the current state of mental health services in the UK. Second, we discuss the challenges facing the sector.

Finally, we discuss the implications of our findings for policy and practice.

1. Introduction

The number of people with a mental health problem in the UK has increased by 50% in the 1990s (Mental Health Foundation 1999). This increase has been driven by a number of factors, including the growing awareness of the need to address the needs of people with mental health problems, and the importance of providing them with appropriate services.

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CHAPTER III

...and therefore, that we may
 ...took, we will
 ...to take
 ...in fact, they are, as proper, and
 ...is connected with the vessel,
 ...not intended, but to
 ...the manner of proportioning
 ...part of it, to the other
 ...are given: then
 ...work, we have at present nothing
 ...W... say to the builder, he furnishes the
 ...to this... from dimension of the spars, but to the
 ...them... makes them: other
 ...are often... to glass,
 ...and manifest discrepancies: the
 ...who suppose
 ...We will com-
 ...the people...
 ...we shall proceed, and draw such in-
 ...may demand
 ...to be 80 feet
 ...and 20 inches in the slugs, strike
 ...on the spar, on or spot-
 ...middle of
 ...length into
 ...the
 ...of setting out
 ...of
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 ...on each end,
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 ...



Figure 1. The rig used for the study. The rig was used to measure the force exerted by the subject on the ropes.

at the fourth spot or end, $4\frac{1}{2}$ inches. Thus we discover that in the slings the yard is 20 inches; at the first setting-off $19\frac{1}{2}$ inches; at the second, $17\frac{1}{2}$ inches; at the third, 14 inches; and at the end, $9\frac{1}{2}$ inches. We have shown another kind of sweep in Fig. 3, that will furnish better proportions than that of Fig. 2: by applying the settings-off as taken from the diagrams to the scale of three-quarters of an inch, we shall discover the variations in the size of the same yard, of the same size in the slings, and an equal number of settings-off. The first setting-off from the sling furnishes the same as the first, $19\frac{1}{2}$ inches; the second, $16\frac{1}{2}$ inches; the third, 12 inches; and the end, $6\frac{1}{2}$ inches. Now, we hesitate not to say, that spar-makers themselves will acknowledge that a yard made by those dimensions would be as likely to break any where else as in the slings, and not any more; of course there should be an allowance in size for the weakening tendency of the sheave-hole, and beyond this nothing more would be required. Fig. 4, Plate 18, is designed to illustrate the division of the circle into degrees or angles; the quarter of the circle containing 90 degrees and forming the square, and one-eighth containing 45 degrees, which is the mitre or the right angle equally divided, and is usually

recognized in the ship-yard as, and taken with, the bevel. It does not, however, necessarily follow, that the mitre can be obtained only in the angle of 45 degrees; the equal division of any angle into two parts constitutes the mitre of that angle; 45 degrees is the mitre of a square; 90 degrees, or the square, is the mitre of the semicircle, or of 180 degrees. It makes no difference how large or how small the circle may be that is to be divided into degrees. The circle of our earth contains no more degrees than that of an orange, and the angles are the same; hence we say, that the only correct mode of taking the dead rise of vessels, or of their sharpness, is by taking the angle in degrees, or by taking the fractional parts of a foot of rise, &c., contained in a foot, which is the same thing; it applies to the rake of masts, the descent a vessel has on the stocks, and of the ways for launching; and we confidently believe that were angular measurements adopted more generally in the ship-yard, much might be gained by way of correcting errors and of facilitating work.

Although much has been said by mathematicians in all ages about the circle, and the determination of the ratio of the circumference to the diameter, yet it still remains a problem for solution, and the circle, in connec-

tion with the straight line, are the only two figures admitted into plane or elementary geometry; and the question may have been often asked, what has geometry to do with the practical operations of a ship-yard? We answer, much more than is generally supposed. Did the operative mechanic mingle the elementary principles of geometry with his daily practice, he would be enabled to cut closer or with more certainty of success. Why is it that the butt of a plank on the luff of a vessel's bow is cut too short or too long? or why does the blacksmith make a band or the grummet of a yard too large or too small? It is because he has never studied the properties of the circle; if he had, he would have learned that his bar of iron should be three times its thickness longer than the circumference of the spar, rudder, or whatever is to be banded, in addition to the weld, inasmuch as the circle is three times the diameter, (or differs but a trifle from that proportion.) The usual mode of determining the circumference from the diameter is as follows, (and is near enough for ordinary purposes :) multiply the diameter by 22, and divide the product by 7, the quotient will be the circumference very nearly. But again, the cone has a prominent claim on the attention of practical men in the construction of ships, as well as other branches of mathematics. The operative mechanic would be awed into wonder, at the astounding intelligence that the sni of a plank may be determined with far greater accuracy by the aid of conic sections than with a rule staff; the blacksmith may also be better enabled to band a bow-sprit cap with a knowledge of the properties of the cone, and yet the circle and the straight line furnish all the figures that are necessary to its practical application.





CHAPTER X.

Steamboats—Ocean Steamers—Coasting Vessels—Vessels Suited to River Navigation.

With feelings of pride and patriotism we launch into the subject forming the van of the present chapter. As the discovery of the art of printing has partially and must finally dispel the gloom of barbarism, so the discovery and application of steam to navigation and the purposes of commerce, tend to elevate the physical and moral condition of mankind. In connection with the history of steam navigation, the name of no individual stands more prominent than that of Robert Fulton, a man of whose genius, indomitable perseverance, and unbending energy, Americans may well be proud. Whether we witness in our imagination his experiments in submarine and torpedo warfare in France, in 1801, or on the 17th of August, 1807, form one of the incredulous company that thronged the wharves of this city to witness his first effort to navigate the Hudson by steam at the then surpassing speed of 5 miles per hour, we must regard him as a man possessing mechanical powers of mind of an extra-

ordinary calibre; inasmuch as his first steamboat was crude both in dimensions and form, lacking that essential qualification, *stability*, and was subsequently widened, in order to afford the necessary amount.

It may not be out of place to furnish a brief description of Mr. Fulton's first effort at steamboat building, more particularly when we are assured that no mechanical drawing of the hull was ever made. The boat was 133 feet long, 18 feet wide, and 7 feet deep, and was subsequently made 22 feet wide, by adding a strip of 4 feet to her middle, which also increased her length to 141 feet. Her bottom was formed of yellow pine plank of 1½ inches thick, tongued and grooved, and set together with white lead. This bottom or platform was laid on a transverse platform, and moulded out with batten and nails. The shape of the bottom being thus forward, the floors of oak and spruce were placed across the bottom; the spruce floors being 4×8 inches, and 2 feet apart; the oak floors being reserved

for the engine, and the spruce for the ends; the oak floors both sided and moulded 8 inches. Her top-timbers (which were of spruce, and extended from a log that formed the bilge to the deck) were sided 6 inches and moulded 8 at heel, and both sided and moulded 4 inches at the head. She had no guards when first built, and was steered by a wheel in a cockpit. Her draught of water was 28 inches. She had 1 boiler 20 feet long, 7 feet deep, and 8 feet wide; her cylinder was 24 inches in diameter, with 4 feet stroke; her wheel was 15 feet in diameter, with 8 arms; the buckets or paddles had 30 inches face, and 2 feet dip; her shaft was of cast iron, 4½ inches in diameter, under the deck, and had a fly-wheel of 10 feet diameter outside of the boat; the arms of the wheel extended below the bottom, and were the source of great inconvenience in shoal water. She was called first the North River, and subsequently the Clermont, in honor of Chancellor Livingston, who resided at Clermont, on the Hudson, about 40 miles below Albany. As no complete draft of the hull of this boat (either before or after she was widened) has ever been shown, the world cannot contrast all the improvements of nearly half a century; but we shall show our readers the second boat, designed and drawn by Mr.

Fulton's own hand in 1808. Plate 22 furnishes an exact copy taken from the original drawing of the steamboat Raritan, built to run on the Raritan river. In shape she differs but little from the Clermont, and with the exception of an amendment in dimensions, and the addition of guards, she is a fair representation of the first steamboat that plied the waters of the Hudson. We shall give Mr. Fulton's instructions for building this boat, as appended to the draft, and directed to Mr. Livingston, in his own words:—

“As you will have more and greater waves than the North river boat, the wheel guards must be so constructed that the head of the wave shall not strike under them. I would finish them as here delineated: they are 4 feet from the water; A A, keelsons for the boiler, 8 feet 6 inches from outside to outside; B B, keelsons for the machinery, 7 feet from outside to outside; C, hatchway to let in the boilers, 8 feet 4 wide, 21 feet long. See Figure the 1st. ROBERT FULTON.

“October 22d, 1808.

“John R. Livingston, Esq.”

We cannot but look upon the first efforts of Mr. Fulton at steamboat building with admiration; possessing a mind in every respect adequate to the gigantic enterprise that lay before him;



for the engine, and the
ends; the oak floor
moulded 8 inch
(which were
from a 10
deck)

was completed in 1808. Page 22
gives an exact copy taken from
the original drawing of the steamboat
designed to run on the River in 1807.
In shape the dimensions but little from
the Clermont, and with the exception
of an amendment in dimensions, and the
addition of masts, she is a fair repre-
sentation of the first steamboat that
ploughed the waters of the Hudson. We
shall give Mr. Fulton's instructions for
building this boat, as appended to the
cylinder-drawing, and directed to Robert Fulton
in his own words:—

General Instructions.—As you will have made good
waves than the North river boat, the
cylinder must be so constructed
that the head of the wave shall not
come under the keel. I would finish
them as here delineated; they are 4
feet from the water; A A, 16 inches; B B,
8 feet 6 inches from outside
to outside; B B, 16 inches; the main
cylinder 7 feet from keel to outside;
the boiler 4 feet 4 inches in the boiler, 8
feet 4 wide, 21 feet long. See Figure
the plan. ROBERT FULTON.

London, 22d, 1808.

General W. H. Kingston, Esq.

We cannot but feel that the
efforts of Mr. Fulton at
this time were indeed
a great success, and that the
success of the Clermont was a great
achievement.



wasting health and life in midnight thought and painful study; dreaming of science in the broken slumbers of an exhausted mind, he steadily pressed on toward the goal of all his hopes, and in the year 1816 had constructed and supervised the building of 15 steam vessels during a period of 10 years, the longest of which was 175 feet.

It would have required a vision of more than ordinary strength to have looked through the vista of time for a distance commensurate with less than half a century to a period when the speed of steamboats upon the same river on which Fulton harnessed his trackless steed, should have increased from 5 to 20 miles per hour, and when the motive power (versus pressure on the boiler) should be increased from that of 8 to 50 pounds per square inch; we say that the mind capable of grasping and keeping pace with such wondrous results, in so short a time, must be expansive indeed; but when we remember that not only this, but far greater achievements belong to America in steam navigation, the commercial world instinctively bows to the fecundity of American *genius*, while her ocean steamers are ploughing trackless furrows in every sea, and leaving their tardy rivals far in their wake. Such has been the progress of steam, that the domain of old Neptune

has been invaded, and as if regardless of his regal wrath expanded in foaming billows, or the caresses of his boundless mirror.

The construction of steamboats has engaged some of the loftiest conceptions of the age, and our steam river navigation still forms a great theatre of nature, inviting us to those bold researches in which science engages with such keen delight.

In our expositions on the laws of resistance, we took occasion to make some deductive remarks on steamboats, which may be found on page 66, and onward. In building steamboats, the first and most important consideration is proper dimensions, without which our hopes for superiority will be futile. There is no analogy existing between the proportions of length, breadth or depth of steamboats, as compared with sailing vessels, (we allude to river boats as now constructed on the Hudson and other rivers.) The reason is obvious to the thinking-man—they are required for great speed, which is only attainable by having great length and a sufficiency of breadth to secure the stability of equilibrium, and no more depth than the grand object at which we aim (*viz.*, speed) requires. The reasons will, we think, appear obvious: first, great length pre-supposes acute lines; or, in other words, two

ends, and but little middle longitudinally ; that is to say, an additional breadth is added to the sides of the model for the purpose of making it sharper ; hence it follows, that if the additional length were added to the ends for the purpose of sharpening them, no addition can be made to the middle in length that will accomplish the same object. We mean by this, that great speed cannot be gained by increasing the length midships, and retaining the same or nearly the same shaped ends as before ; this, however, is often done to secure a light draught of water, but always at the expense of speed ; true, we may gain an equal amount of stability with less breadth in the boat having short ends and a long middle, and in addition to this the boat is made to show a smaller registered tonnage. But look at the consequences ; the boat is shorn of her speed from 1 to 5 miles per hour, and at once set down as a second class boat, when she might, with the same cost, have been rated a first.

Steamboats in this age of the world are rated by their speed, or in accordance with the degree of speed attained ; and we think we hazard nothing in stating it to be our firm conviction, that steamboats may be built that would be able to make the run to Albany within 6 hours, at no greater cost than

some other boats that could scarce make the run within 8 hours. This enterprise can only be accomplished by allowing the builder to have discretionary power in dimensions, shape, and the weight of the boat ; and the engineer to proportion the engine and boilers in accordance with his superior judgment ; and the captain to have nothing to say farther than to judge of the quality of the materials and of the work. We are persuaded that it would be much more difficult to secure such an arrangement, than to accomplish the work of building the boat to perform the trip in the given time ; consequently we must allow those passengers whose business compels them to travel in haste, to take the railroad, until captains and owners shall have learned, that *that* which *they* cannot do, can be done by mechanics.

A light draught of water seems to be the grand desideratum with the greatest portion of steamboat men ; but unless it is obtained at the expense of weight, or by other means than those generally adopted, it is only secured at the expense of speed. It would be hazardous to attempt to furnish any standard of proportionate dimensions for steamboats ; the circumstances are so variable under which steamboats are built, that what would be a just proportion in one case, would be far

from the same in another. The engine and boilers are so variable in the altitude of their centre of gravity, that the dimensions and the power should be taken in connection; under ordinary circumstances from 9 to 10 feet of length to 1 of breadth, and 3 of breadth for 1 of depth, are deemed just proportions for river boats with beam engines. Many persons have supposed, that if the relations between the breadth and depth remained the same, that the length might be increased to advantage for speed. This is not strictly true; the stability is sensibly affected when this is the case; but it does not follow that the breadth should be increased on all parts of the greatest transverse section in the same ratio; our object may be gained by increasing the breadth at the load-line of flotation, while at the middle of the bilge it remained as before. We have already remarked, that an easy bilge was an essential qualification for high speed, and that a large column of water should pass between the wheel and the bilge. This answers a two-fold purpose: it cuts down the resistance, and at the same time sustains the boat where buoyancy is most required; and while it is absolutely necessary that the boat should be entirely flat, that is to say, that she should have little or no dead-rise; it is also still more essential that

she should present but little really flat surface to the fluid. Abundant proof of this is afforded almost every day of the travelling season on the Hudson—a river doubtless unsurpassed for its natural facilities afforded for experimenting on a wide and extensive scale on steamboats—being at some parts wide and deep, while at others it is narrow and shoal; and again, in other places narrow and deep, while at another we find it wide and shoal. Thus the observing mechanic may readily determine the best shape for speed, even though he be unskilfully versed in the philosophy of nature's laws. The boat, with an extensive flat or straight surface on the bottom when in shoal water, will generate a much larger wave on each quarter than the boat having less, and will actually ground when another will pass over, that would actually draw more water when at rest; the same results are consequent upon the straight side longitudinally when the boat is near the shore. Few indeed there are who can form a just conception of the effect upon the speed of a steamboat when in shoal water, or in a narrow pass of the river.

With regard to the proper shape for speed, we will say, that the greatest transverse section or $\otimes$ frame is found to be well adjusted when in the centre

of length, and the buoyancy equally distributed each side of the longitudinal centre of length. The centre of effort should be higher than in sailing vessels, to counteract the leverage of the engine, or its centre of gravity over that of the centre of displacement, it being usually above the deck of the boat. Although the displacement on the two ends of the boat should be about equal, it does not follow that they should be of the same form, either at the line of flotation or on any part below that line; the sharpest end of the boat should go foremost, and yet it must be observed, the after end cannot be a great deal fuller than the fore end, or the centre of buoyancy would not be at the centre of length; this is accomplished by making the lines on the bow hollow longitudinally; this form of line makes the least disturbance, and if sufficiently acute, will not translate the fluid into foam by throwing it off from the bow; we may rest assured, that there is an unnecessary amount of resistance where the fluid is either thrown off or the smallest wave generated. A given amount of fullness may be forced through the water with less disturbance, by entering with an acute line and gradually increasing the angle of resistance as we advance; whereas, had we commenced with the same angle that we present two-thirds of the distance from the stem to the $\odot$, we should have lifted a sheet of water close to the stem, which would again meet us with redoubled force, and must again be thrown off in consequence of the accelerated force with which it moves. It should be remembered that this sheet of water raised on the bow generates a wave, (and that wave, unlike one generated by the friction of the wind, that merely oscillates and has no progressive motion;) this wave meets the bow again farther aft, but the resistance is increased by the accelerated motion of the wave, which is thrown off and again returned with increased force thus a succession of concussions take place, that diminishes the speed to a very great extent. It requires but a glance at the inevitable results, to enable us to imagine the amount of resistance on the bow of a steamboat, when we remember that the vertical pressure on each square foot of surface of fluid equals 2,160 pounds, and that there must be an excess of pressure on the bow before the wave can be formed. The pressure on the bow and stern must be equal to the whole power of the engine; and as the speed of the boat is increased, the wheel makes more revolutions with the same pressure of steam. The number of revolutions of the wheel in a given time, mul-

tiplied by the periphery of the wheel taken at the centre of the bucket or paddle, furnishes data for determining the relative speed of a boat ; but there is a certain allowance to be made for what is usually termed the slip of the wheel, which is the yielding property of the water ; this amount is usually set down at 20 per cent., but is variable, consequent upon the amount of dip to the bucket, the number of arms in the wheel, &c.

It must be quite apparent that a steamboat cannot turn her wheel around as often in a given time when made fast at the wharf, as when in motion or under way, though the same amount of power be exerted ; the same may be said with equal propriety of a boat that has more resistance than another with the same sized wheel and power. The problem is a plain one, and we think may be readily understood by the apprentice at the grindstone ; when the man of the axe bears harder, one of two things is the consequence, either the stone makes a less number of revolutions per minute, or the boy applies more power. Much has been said relative to the comparative efficiency of the large and small water-wheel, the increase of power necessary to be applied to the large wheel may also be considered, if we would make the same number of turns. We will remark,

that although the large wheel is without doubt favorable to high speed, (provided we have steam to handle it,) yet if we determine to obtain great speed with a large amount of power (and a large wheel) from a bad shape, we may get disappointed. We may make the boat bear a load of resistance beyond her strength, and shiver the wheel into fragments with power, and she may go no faster. There is a certain amount of speed adapted to every shape, and beyond this she will not go ; but it does not follow that when the bow, for example, has been driven up to its highest speed, that the stern has also attained its greatest speed. The bow is not always adapted to the stern, or the stern to the bow ; indeed, it is often quite the reverse ; the most heterogeneous quality may be found on one end, while the other may possess all that is desirable. How often do we see steamboats settle at the stern when under way. This is owing to the disparity in shape of the two ends ; one end being adapted to a much higher speed than the other. There is a peculiar qualification that steamboats should possess, in order to this adaptation, and without it the ends cannot be adapted the one to the other. It is not enough to know that the centre of gravity of displacement is in the centre of length longitudinally, or that it is at a given point ; but we should

also know that it traverses a vertical line, not only at the several lines of flotation, but from the base to the load-line, and a wide departure from this track will be perceptible in the performance of the boat.

It does not follow, from what has been shown, that the two ends must of necessity be alike; there may be the widest departure from sameness, and yet this relation still exist between the two ends. It must be quite apparent to the reflective mind, apart from experimental test, that if one line is adapted to the element, with the centre of gravity at a given point in the longitudinal length, another line would also be equally as well adapted to the element with this central point in vertical line with the one above or below, when at the same speed. (Were the several sections driven at a different speed, then the case would be different; but while all parts of the boat go at the same speed, and the element is of the same consistency at every parallel of altitude,) experiments have been made upon models that have shown the centre of gravity of displacement to sag aft at the surface from a vertical line, but still there was a uniform relation. The Russell theory, based on experiments, recognizes those relations; those of Mr. Stevens would also seem to corroborate them; but we

have less confidence in those experiments than the projectors themselves. There are some circumstances connected with the experiments that fail to furnish analogies in all particulars: for example: a canal is not the place to try those experiments, and simply because the water is shoal, and the sheet narrow; consequently, the bottom and sides of the canal have a very great influence upon the results. While we assume, and we are really disposed to believe, that the resistance belongs to the boat, a very large share belongs to the bottom and sides of the canal, which under some circumstances, would amount to more than half. Were it possible to accumulate the same amount of resistance on the vessel as that shown by the indicator, she would be torn asunder. Experiments for quite a moderate speed will or may furnish data, but for high speed, under the influence of an extraordinary amount of power, the river itself is, comparatively speaking, too small. In the canal we shall find that as soon as we disturb the water on the banks, we commence towing not only the vessel, but all the water in the canal. Hence we say, the wider and deeper the river upon which experiments are made, the more reliable is the data furnished.

With regard to our present knowledge of shape for speed, we have no

hesitation in saying, that a speed of 25 miles per hour may be obtained, but the mechanic who undertakes the enterprise must be free from the trammeling influences of captains and owners. With regard to the shape of steamboats for speed, like other vessels, much depends upon the dimensions.

Many men lay large and heavy claims to experience, and upon this they lay a foundation broad and deep for a fine spun theory, that would lead the casual observer to believe that narrow ships or steamboats would roll less than wide ones. But the discrepancy in their theory becomes apparent, when we remember that the advocates for wide vessels do not demand a greater area of load-line than those who adhere to narrow vessels; the difference lies just here: the advocate for narrow vessels depends on dimensions alone, while the advocate for more beam bases his claims for beam as a means of obtaining the required shape: he does not require beam for the purpose of extending it from one-half to two-thirds of the length of the vessel; he requires more beam than is usually given for the purpose of making a round side line from the line of flotation downward. If proof were required of the truth of the assertion we have made, we refer to the fact of the increased stability of our ocean steam-

ers, when the coal remains in the side bunkers and is used out of the ends of the vessel first; and on the contrary, when the coal is used out of the side bunkers first, and left in the ends, the vessel rolls and becomes unsteady, with first one wheel immersed, and then the other. We think those who advocate narrow vessels for stability will find it difficult to digest this fact, in connection with the assumption that because a vessel has the apex of the sea on one side, the trough must of necessity be on the other, and that the leverage is greater in proportion to any extension of the breadth, and the vessel must of necessity roll more. But there is another fact that belongs to this question of the sea on one side and the trough on the other; the advocates of narrow vessels must remember, that the stability depends as we have shown upon the altitude of the centre of effort; the higher this point, the more stable the vessel, provided the shape and stowage do not conflict with the known laws that govern stability in these particulars. We say that it is only those who take a superficial view of the matter who advocate narrow vessels, inasmuch as the known laws of geometrical science, in connection with experience *versus* experiments of a tangible nature, is against them. With regard to the weight of

steamboats, it seems to us that some remarks would be in keeping. When great speed is the desired object in building steamboats, all unnecessary weight should be dispensed with; and we would here remark, that the strength of steamboats for river navigation should principally rest in the bottom, when the engine is low pressure, and secured to the same. The distribution of timber for strength is a matter that requires the exercise of some considerable amount of mechanical skill; centre, engine, sister and bilge keelsons are of the utmost importance to the steamboat having her engines in the hold, and these should be square fastened with blunt bolts. There are many parts of steamboats and other small vessels where screw-bolts should be used, where the amount of surface through which the bolt is to be driven is not commensurate with the strength of the material or the strength required. An easy or light draught of water being often indispensable to river navigation, it is very generally sought in the shape at the expense of speed, whereas it should have been looked for in the dimensions and weight of material; for very light draught iron boats are superior to those of wood. It would be a difficult matter to build a boat of timber of any considerable size and sufficiently strong,

that would navigate a stream of water 13 inches deep, and yet the same may and has been accomplished with iron. A larger amount of strength with the same weight, or the same amount of strength with less weight, may be obtained of iron than of wood. With regard to the resistance of the two kinds of materials, timber presents more than iron; hence it follows, that if two steamboats were built alike in shape, and brought to the same draught of water, and the same amount of power applied to both boats, the iron boat would be found to be faster than the one built of wood; the reasons will appear obvious if we but reflect that the timber is porous, and that the molecules or particles of water filling the orifice must be rent asunder in their collision with those of the exterior surface of the passing boat. This separation exhausts an enormous amount of power; the proportions of which may be judged, if we but witness the effect when the operation is in accordance with the known laws of hydraulics: let a pipe of any given size be the conductor of a stream of water, it may be to convey the stream in longitudinal or vertical directions, it matters not which, the pipe may be assumed to be of parallel opening its whole length; we may now determine precisely the amount of water that it will dis-

charge per minute with a given head, or with a reservoir of a determinate altitude; the pipe may now be enlarged in any part of its length between the ends, and again the discharge may be determined per minute, and it will be found that it is less, although the pipe has been made larger, and is placed in the same position as before, under the same head of water. It is the disruption of the particles that remain in the recess of the pipe that checks the passage; so with the plank on the steamboat's bottom; and can only be counteracted by metal sheathing, which for shoal water is difficult to keep properly adjusted. It is in this particular that iron presents (for speed) a better surface than wood. There are other circumstances under which iron as a material for building vessels exhibits its advantages over that of wood; in the West Indies and some parts of South America, and even the southern parts of the United States, timber rots in a very short time, in consequence of the peculiar state of the atmosphere generating deleterious gasses rapidly, which causes wooden vessels to rot in a very short time; hence we say, that for low latitudes where vessels cannot be abundantly ventilated, they should be built of iron, if durability is a consideration. The principal objection to their introduction on an extensive scale

in this country, is their cost, inasmuch as the expense ranges from 25 to 30 per cent. more than wood; this must prove a barrier to the construction of large sailing vessels of iron in this country, where timber is abundant, and the chances remain that a vessel may pay her first cost with interest, wear and tear, long before she is completely rotten.

In England, iron vessels of all sizes, and almost all kinds, have been, and continue to be, built. English authors have endeavored to show all, and even more than all, the advantages that accrue from building of iron; but while we are quite willing that their arguments should be heard, we are disposed to correct any error into which they may have fallen, in their eager haste to show the superiority of iron over wood.

Mr. Grantham, President of the Polytechnic Society of London, in a work entitled, "Grantham on Iron, as a Material for Ship-building," sets down as one of the advantages, the correctness with which the draught of water may be ascertained, in proof of which an instance is cited, in which the draught of water was not determined within 2½ feet on a steamer built of wood.

Lest the reader should be led astray by similar statements, we would add,

that had the builder of the steamer in question taken a few lessons in the United States, he would have been able to have approximated the draught of water of any vessel before launching, without going into the calculation. That the precise or exact draught of water may be more readily determined when the material of construction is iron, cannot be doubted; but we are persuaded that a mechanic who had never before seen a vessel, would be able to mark her draught within 24 feet without the use of figures, or quite as near as the case cited.

Iron steamboats possess another advantage which should, we think, recommend them for the Mississippi and other Western rivers. The advantage alluded to consists in the water-tight bulk heads, which effectually prevents the boat from sinking, even though one part should be snagged and filled with water. The corrosive quality that stands connected with the use of iron for vessels to navigate the ocean, in connection with their cost, must be a drawback on their extensive use.

As it regards shape for high speed in river steamboats, we desire to stand fully committed, whatever may be the strength of that tide of influence, made up of prejudices, and completely interwoven with the subject of steam river navigation. First, there is an

endless variety in opinions with regard to the proper shape for high speed, apart from the proportionate principal dimensions. It has been set down as an axiom, that the highest degrees of speed were only attainable by the longest boats having the proportionate amount of power; but what that proportion amounted to has never been defined. Almost from the commencement of that spirit of rivalry that has marked the progress of steam on the Hudson perhaps more than on any other river in the world, there has been a disposition manifested by the organization of companies to monopolize the travelling facilities on this majestic river; but not the least prominent feature of these aggrandizing efforts is, that of claiming that their knowledge was commensurate with their experience, and their experience with the amount of means expended and efforts made to maintain the supremacy. At intervals, however, in the history of those efforts, there has arisen some indomitable spirits who have dared to undertake the construction of steamboats for high speed of much smaller size, and not unfrequently have they borne off the palm of victory over their more powerful competitors. Among those thus successful, stands the steamboat **REINDEER**, the lines of which are shown on Plate



Date	Description	Amount
1890	Jan 1 Balance	100.00
1891	Feb 10 Cash	50.00
1892	Mar 15 Cash	75.00
1893	Apr 20 Cash	120.00
1894	May 10 Cash	80.00
1895	Jun 15 Cash	90.00
1896	Jul 20 Cash	110.00
1897	Aug 10 Cash	130.00
1898	Sep 15 Cash	140.00
1899	Oct 20 Cash	150.00
1900	Nov 10 Cash	160.00
1901	Dec 15 Cash	170.00
1902	Jan 20 Cash	180.00
1903	Feb 10 Cash	190.00
1904	Mar 15 Cash	200.00
1905	Apr 20 Cash	210.00
1906	May 10 Cash	220.00
1907	Jun 15 Cash	230.00
1908	Jul 20 Cash	240.00
1909	Aug 10 Cash	250.00
1910	Sep 15 Cash	260.00
1911	Oct 20 Cash	270.00
1912	Nov 10 Cash	280.00
1913	Dec 15 Cash	290.00
1914	Jan 20 Cash	300.00
1915	Feb 10 Cash	310.00
1916	Mar 15 Cash	320.00
1917	Apr 20 Cash	330.00
1918	May 10 Cash	340.00
1919	Jun 15 Cash	350.00
1920	Jul 20 Cash	360.00
1921	Aug 10 Cash	370.00
1922	Sep 15 Cash	380.00
1923	Oct 20 Cash	390.00
1924	Nov 10 Cash	400.00
1925	Dec 15 Cash	410.00
1926	Jan 20 Cash	420.00
1927	Feb 10 Cash	430.00
1928	Mar 15 Cash	440.00
1929	Apr 20 Cash	450.00
1930	May 10 Cash	460.00
1931	Jun 15 Cash	470.00
1932	Jul 20 Cash	480.00
1933	Aug 10 Cash	490.00
1934	Sep 15 Cash	500.00
1935	Oct 20 Cash	510.00

23. This boat, built during the present year, 1850, by Mr. Thomas Colyer, although not of mammoth proportions, (and consequently not of gigantic size,) is superior for speed, and is doubtless at this time the fastest wooden river boat of her length in the United States. She has the wave-line bow, and it would be found a difficult matter to obtain an excess of speed in the same length with the same amount of power, without reducing the weight, (which it will be seen is by no means great.) The Reindeer has been termed a 24 mile boat; that is to say, she can run 24 miles in an hour, in still water, without much extra effort by way of making steam.

Her dimensions are as follows: length, 260 feet; breadth, 34.08 feet; depth, midships, from base line to deck line, round of the beam deducted, 9.75 feet; area of her immersed midship section, 119 square feet; diameter of cylinder, 56 inches; stroke of piston, 12 feet; diameter of water-wheel, 34 feet; face of wheel, 9 feet 6 inches; width of bucket, 24 inches, calculated to dip 9 inches below the surface. Her engine is that known as the vertical beam engine; balance valves with Stevens's cut-off; its weight, in connection with that of the gallows frame, (which is set down at 16,000 pounds,) is computed at 201,019 pounds; the water-

wheels, 39,300 pounds. The weight of the boiler equals 87,847 pounds; the water in the same, 91,847 pounds; displacement or weight of the boat at 4 feet draught of water, 447 tons 417 pounds; weight of engines and boilers, with water in the same, 187 tons 1,133 pounds; weight of joiner's work, 63 tons 111 pounds; weight of furniture and outfit, 17 tons 320 pounds. Total weight of engines, boilers, joiner's work, furniture, and outfit, 267 tons 1564 pounds; leaving for the weight of the boat 179 tons 1090 pounds, which is a very close approximation to the exact weight of the hull.

In connection with the speed of steamboats, the power applied, and the manner of computing it, stands intimately connected with the subject. In Europe very generally, and in this country to some extent, the power of steam vessels is computed by horsepower. The great bulk of operative mechanics do not fully understand this manner of computing power, and we have ever regarded it as loose and indefinite. There is a distinction (that is not always regarded) between the pressure indicated by the steam guage at the boiler, and the effective power applied as resistance at the water. The principal cause is found in the loss occasioned by the friction of the journals, and in the transfer of the

steam from the boiler to the cylinder. The sum total of this is set down at .65. The horse-power is determined in the following manner: multiply the *area* of the piston by the pressure of steam, as shown by the guage per square inch, plus the pressure of the atmosphere, and that sum by the velocity of the piston per minute, divide by 33,000, (which is the weight in pounds, it is assumed that a horse can raise one foot high in one minute,) and multiply the quotient by .65, which will give the effective power for steam engines. Example:—

$$\begin{array}{ccccccc} \text{Area} & & \text{Pressure} & & \text{Velocity of} & & \\ a & \times & p & \times & v & \times & .65 = \text{Horse-} \\ & & & & & & \text{power effectual.} \end{array}$$

When the steam is cut off at half stroke (or when the supply of steam is withheld at half the stroke) in the cylinder, there is another drawback which reduces the effective power from unit to .847, inasmuch as .847 is found to be the multiplier for 2; this may be readily understood if we but remember that in cutting off the supply of steam at half stroke, the

only power that can be obtained for the remainder, or the other half of the stroke, must be obtained from the expansion of the steam, which loses part of its heat, (and consequently part of its power,) in the expansion; hence we have $\frac{n \text{ stroke}}{12} \div \frac{\text{feet}}{6} = 2$, the multiplier for which is .847. Suppose the diameter of a cylinder to be 72 inches, the stroke of piston 12 feet, pressure of steam per guage, 40 pounds, as shown by the steam guage, cut off at half stroke, (or half the length of the cylinder,) number of revolutions per minute 22, required the horse-power. First find the mean effective power per square inch in the manner we have already shown, the value of 2 being the multiplier, which is .847, (see Haswell,

$$\begin{array}{ccc} \text{Pressure} & \text{Atmosphere} & \\ 40 \text{ lbs.} & + 14.7 & = 54.7 \times .847 = 46.33 \end{array}$$

pounds as the mean effective pressure in the cylinder for each square inch of its area. To find the horse-power, find the area of piston—

$$4071.5 \times 46.33 = 188632.595 \times \overset{\text{Feet per minute.}}{528} = 99598010.16 \div 33000 = 3018 \times .65 = \overset{\text{Effective horse-power.}}{1961.7}$$

Some farther expositions in relation to the water-wheel of river steamboats may be necessary. Some boats have been found to have attained a greater speed when brought down in the water

by freight or passengers several inches, than they did when light, thus affording the most conclusive evidence, that had the wheel been larger the boat would have performed better, inasmuch

as the same amount of power would have been applied with less steam, for it should not be forgotten that a bulk of steam equal to the cubical contents of the cylinder is lost at every revolution, even though we cut off at half stroke; hence, it is plain, that unless an even pressure is kept in the boiler there is a loss of power, and more would be gained by increasing the size of the wheel if we would keep the power at the same altitude. But there is another view to be taken, which augments the advantage of large wheels in diameter; they operate more direct on the water, and although more power is required to turn them, or to make the same number of revolutions in a given time, yet all the available power of the boiler and engine is applied at the water with less difference between the speed of the wheel at its periphery and the boat, and consequently, less slip or slide of the bucket. We would not be understood to say, that the slower the wheel the faster the boat, but we do say, that when the wheel turns fast enough to reduce the pressure in the boiler, we require more wheel or more boiler. This may be clearly illustrated in the steamboat at the dock with the engine in operation—the same pressure of steam will not turn the wheel as fast as when the boat moves ahead; and while the boat remains at the dock

we may have steam enough, but loose her fasts and let her go, and we soon see the difference. This leads us to another truth that should also be remembered—the faster the boat itself is capable of being driven, the less resistance with the same sized wheel, and, as a consequence, the wheel will turn faster with the same power and use more steam; so that as we diminish the resistance on the boat, we must increase it on the wheel, to keep the same amount that a slower boat would have.

We have been led to these remarks, upon witnessing the wholesale blunders made upon river steamboats in relation to the proportion existing between the boiler and wheel, by men whose claims to a registry in the calendar of *common sense*, (in this as well as in other matters,) were recognized on all sides apart from a knowledge of the science of mechanics. It should also be remembered that a saving of steam is a saving of fuel, and a saving of fuel is a saving of dollars. Most of the engines of the river boats of the United States, excepting those of the Mississippi, are high pressure condensing engines, although denominated low pressure—a term belonging properly to those engines only that carry a pressure in the boiler not exceeding that of the atmosphere, or 15 pounds per square inch.

Much might be said in relation to Stevens's new plan to increase the speed of steamboats, by interposing a stratum of air between the *flat* surface of the bottom and the water. Little, however, is known in relation to the final results of this experiment by Mr. Stevens himself; but this much appears to be quite conclusive, that he has succeeded in securing a rate of speed superior to that of any wooden boat of equal length on the Hudson; and this has been secured upon an iron boat of some 270 or 280 feet long, of a shape the most heterogeneous for high speed. Mr. Stevens has seen fit thus far to divulge but little in detail of his method of operations, although the right to the invention has been patented both in Europe and America some years since; as a consequence we are unable to anticipate what might be accomplished, provided the invention could be applied to a good shape for speed.

Having accomplished our purpose in relation to steamboats, we shall proceed to inquire what are the most essential properties required for steamers suited to navigate the ocean. Our readers are doubtless familiar with the achievements of American steam-ships, and it seems only necessary that we should show the qualities requisite to place the ocean steamer at the head of

the list of wondrous achievements consequent upon American genius, having already shown that it is to the United States that the honor belongs of first embarking in this noble enterprise.

The silent observer beholds with wonder and admiration not only the speed, but the regularity of steam-ships as they furrow a trackless path between the Old and New World, notwithstanding the ocean may be lashed into furious, rugged, and frightful precipices by the friction of the wind; yet she seems to tarry not, her course is onward, as if to hurl defiance at the watery blast. Here lies the great secret of success in steam-ships, viz.: their regularity in the length of their voyages, while running at the same place, or plying between the same ports. If storms retard their progress so that, for example, the voyage between New-York and Liverpool varies from 11 to 13 days, they cannot be depended on, and in this particular have but little advantage over the sailing ship; for little doubt exists that there are sailing ships now built that would not vary more than 10 to 12 days in the length of their voyage for a year at a time. The performance of the Canton packet ship *Sea Witch* abundantly warrants us in this assertion; and her last voyage to San Fran-

REGISTERED TONNAGE	{ 170 feet, 3 in.	{ 9074 tons.	CAPACITY FOR CARGO, 1,100 tons.
	33 " 11 "		
	19 " —		

Water Lines 2 feet apart. Line, 6 feet 24 in. at Cross Seam. all taken from frame U, and are found in their respective columns T and Rise, 6 degrees. Height, and 8 in. at Rail.	Cross Seam square at Top Height. Sided 33 in. at heel, and 15 in. at Cross Seam. Stern Rakes at Rail Height on centre, 8 feet 14 in. Stern Rakes at Top Height, 10 in. at Main Height, 9 in. at Top Height, and 8 in. at Rail.	Timbering room, 8 feet. Heel of Post, 4 feet 6 in. aft of Frame 30. Rakes, 2 feet 10 in. on 7th Water Line, 10 in. at Main Height, 9 in. at Top Height, and 8 in. at Rail.	Measurements for the Rake of Stern are Stern Rakes at Rail Height on centre, 8 feet 14 in. Stern Rakes at Top Height, 10 in. at Main Height, 9 in. at Top Height, and 8 in. at Rail.
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REMARKS.—This, although a square-stern ship, was built without stern frame, as illustrated in Plate 17.

cisco from this city in 97 days, shows that there is much room for improvement before a steam-ship could perform a similar voyage.

It may be said that steam-ships are not designed for long voyages; this we admit, in their present state of advancement; nor are they best adapted for short voyages, unless regularity be stamped on their performances or equality on the length of their trips. Steam-ships are costly and expensive, and unless they fully answer the object designed, they are unprofitable, and it does not require much sagacity to discover that as soon as they cease to pay, they will be abandoned for other than mail and war purposes.

It must be quite apparent that steam-ships cannot successfully compete with sailing ships for freighting purposes, for this reason, if they have any considerable capacity for cargo, they are liable to detention on account of storms, which will lengthen the voyage, and render it of uncertain length. The merchant will not pay extra freight unless he is certain that his goods will be conveyed to their port of destination within a definite time, and we at once discover that the steam-ship has not only more expense to encounter, but carries less freight, in consequence of the engines and coal occupying a large portion of her capacity for freight.

Thus we discover that to make a steam-ship profitable for freighting purposes, she is unfit for the conveyance of passengers and the mail, inasmuch as passengers and letters require a speedy conveyance; hence, it must be plain even to the casual observer, that the most desirable quality in steam-ships is speed, but to acquire this, we must sacrifice many of the hereditary notions that pertain to sailing vessels. An ocean steam-ship, in crossing the Atlantic, should never vary more than a few hours in the length of her voyages; this would inspire confidence in this class of vessels, and secure all the passengers. To accomplish this they require a reserve of power of at least one-third of the entire power of the engine; this power should be applied when the winds are adverse, to enable the ship to maintain an equilibrium in speed. It is vain and futile to think of doing this unless the ship be very sharp longitudinally, so much so that at her highest speed she will not generate even the smallest wave. It has been found that instead of applying more power in a storm or gale of wind, it is necessary to apply less to save the ship. The full bow generates resistance to the wave, and causes it to strike with destructive force, and between the force of the wave driving in the direction of the stern, and the engine driving in the

direction of the bow, the ship labors in every joint if the equality of power is maintained, and the consequence is, the power must be reduced; whereas, had the ship been as sharp as she should have been longitudinally, she might have not only braved the storm, but maintained her original speed by the use of the reserve power. We say that ocean steam-ships cannot be made too sharp. If the bow be so sharp that it has no buoyancy, or very little, it can be sustained, but if it is full, it cannot be kept down when submerged in a sea; the consequence is, the engine is unsupported—the ship being sustained by the ends, and very soon shows the result by straining both the ship and the engine. That part of the ship in which the engines and boilers are located, must be supported by the water; the engines have their own work to do without holding the ship when the water refuses to do it. It has been said that when the bow is very sharp it is also very wet—that the sea makes too free a use of the deck forward. This need not be so; the bow is improperly formed when this is the case. The sea may be parted in such manner as to throw off its bulk from the ship.

It is held as an axiom that a fast ship must of necessity be a wet ship. That fast sailing ships are in general

wet, cannot be denied, but it is in most cases consequent upon an improper distribution of sail; the leverage, however, is different in the steam-ship, the bow is not depressed, but is raised. If the steam-ship is as sharp as she should be, no matter how much power is applied, she will not herself make the wave upon which she rises. The less motion the ship has, the faster she will go, and not only so, but the safer she will be, inasmuch as it is the roll and pitch that endangers the ship by straining the engines, and is so annoying to passengers. Hence we say, let the bow be long, and as sharp as the length of the ship will admit of; and in order to keep it dry, let the flare be carried close up to the rail, in order that the sharpness may be continued above the line of flotation. In addition to this, the bow should be deeper than the stern; that is to say, from the line of flotation to the rail on the bow should be on a steamer of any considerable size (and one less than 2000 tons is a small affair) from 5 to 6 feet higher than that of the stern; and if the line of flotation is sharpest at the commencement of the bow, and gradually fills out until it reaches the middle of the same, from which point it again commences to sharpen, and continues to do so until it reaches the greatest transverse section, (which may be aft of the centre of

length,) and as soon as we reach the extreme breadth, commence losing the same as we approach the stern; in the same manner we shall accomplish what we aim at as far as the line of flotation has an interest in this matter. Thus we discover that the bow, as described, extends from the stem to the $\otimes$ frame, or to the greatest transverse section, and that the sharpest part of the bow is at the wood ends; this is a property of hollow parallel lines to the line of flotation, while the round line, no matter how sharp, makes the fullest part of the bow at the wood ends; this causes the water to rise and generate a wave, which is continued when the ship is driven at any considerable speed; in a word, the lines of a steamboat or ship should have no sameness. As soon as the greatest breadth has been reached, we should commence retiring at once toward the end; but this shape contemplates stability lengthwise, and is consequent to some extent upon dimensions. The draught of water and weight to be sustained must be brought into the account, or we reckon without our host. The breadth must also be considered, and for stability we require more than the usual proportion for sailing ships, as we have shown on page 43, popular prejudice to the contrary notwithstanding.

Our remarks upon rolling, and the

cause, have been clear and conclusive in our own judgment, and if experience is any test, we are also supported in a good degree. There is, however, another feature connected with a good degree of breadth for steam-ships that should settle the point in the minds of those whose experience is hereditary as well as their opinions. It is admitted on all hands that an ocean steamship should, if possible, have the same dip to her wheel the whole length of the voyage; in other words, if the wheel has the right amount of dip at the commencement of the voyage, and has less at the termination, it does not have enough—consequently the nearer this dip at the commencement and termination of the voyage can be equalized, the faster the ship will go. The question at once arises, what has this to do with the breadth of the ship? We say much; 800 tons of coal removed from a narrow ship with a known displacement, will raise her higher out of the water than if the ship were wider with the same displacement. There is nothing mysterious about this; two ships of the same displacement, the one narrow and the other wide, the narrow ship in discharging 500 tons is raised out of water 6 inches more than the wide ship, and, as a consequence, has 6 inches less dip to her wheel, which, had the two ships

an equal amount of resistance, power and speed would place the wide ship in advance of the other at the termination of a voyage together, and although the narrow ship might secure an equal amount of resistance at the wheel, by securing the same dip, it would be at the expense of more resistance on the ship, on account of water she might pump in tanks to equalize the dip of the wheel; for it is plain, that if she burned less coal, she would make less steam, and, consequently, would have less power; for after all that can be said about power on steam vessels, the steam is the power, and a given amount of the same kind of fuel will, under the same circumstances, make a given amount of steam. Thus the adherents to narrow steam-ships are driven to the necessity of starting with more dip than they should have, and even more wheel than they can properly manage to continue so, until the ship has been lightened by the consumption of coal, or else at the termination of the voyage the wheel is making foam on the surface of the water, and rolling alternately each wheel out with little effect, straining the engine to no purpose.

From what has been shown, it must have been discovered that it is all-important to determine the diameter, and, as a consequence, the dip of the wheel,

before we commence building the ship, and learn before we adopt the model, even if it be made, how much the consumption of the necessary fuel will lighten us, and what dip will remain, and if we find it necessary, increase the proportion of breadth fully up to what has been shown on page 43. We need have no fears in relation to the roll of the ship; the altitude of the centre of effort, the location of the centre of gravity, and the shape of the bilge determine this quality. We, as Americans, have been led into this error of narrow steam-ships by England; and surely no steam-ships roll more than the Cunard line, with the fullest part of their line of flotation at the two extremities; they hang by the ends, (as if in a turning lathe,) and roll from side to side, taking the water over the rail forward in astonishing quantities.

England, although a commercial nation, and as her Premiers and leading statesmen have boldly announced, *her policy is strictly commercial*, yet her hereditary institutions have stamped her commercial progress with a mildew that would fetter, if not endanger, American *genius*; and we unhesitatingly say, that America must take the van in steam as well as in other ships; and not only so, if steam-ships are to be the commercial watch-word, they must attain a greater degree of

speed than they have ever yet attained—the Atlantic must be crossed in eight instead of ten and a half days, and this as the general average. Let not our readers be startled at this announcement, it can and will be done, and even more, if steam-ships continue to carry the mail and passengers between New-York and Liverpool. Steam-ships must advance in speed as well as other ships. The Californias have opened a trade for fast sailing ships, that will in a few years astonish the most sanguine in relation to the speed of sailing ships; already are ships being built for this trade from 200 to 220 feet long, and other dimensions in proportion. By the aid of these fast sailing ships, merchants and speculators can obtain the returns of cargoes bought on time before their notes become due; thus we discover the spirit of American movements in commerce is onward, and if steam-ships do not advance, sailing ships will.

It is not only important, in calculating for a steam-ship, that we should have a determinate line of flotation, but we should know the amount of displacement below this line of immersion; and more than this, we should locate the centre of gravity of this entire bulk of the immersed part, and we should also know where to locate the centre of weight, in order that the ship

may have her proper trim, without being compelled to carry coal where we do not want it for the purpose of trimming the ship, as is not unfrequently the case. This is rendered necessary in consequence of the bow having less displacement than the after end; this would seem like placing the wrong end ahead; but such is the fact, that for high speed the bow will require less buoyancy than the stern. If we divide the length on load-line into two equal parts, the consequence will be, that the ship would set by the head when launched, and if the centre of the weight of the engine were located at the centre of buoyancy, the ship would continue to be by the head; her trim would not be altered. This will become apparent if we will but reflect that the bow, being the longest, consequent upon its being the sharpest, balances at a line of immersion equivalent to its weight; the stern, being fuller, requires to be less immersed than the bow, to equilibrate; hence we discover that if the engine were equally divided, and the one half placed on the centre of gravity of the bow, and the other on the centre of gravity of the stern, the bow would settle down faster than the stern; and, as a consequence, if the centre of the weight of the engine were to be placed at the centre of buoyancy, the effect would be the same, though

aft of the centre of length, hence we discover that something more is required. The discrepancy lies here ; the amount of buoyancy between the centre of gravity of displacement and the centre of length should be determined, and an equal amount aft of the centre of gravity of displacement should be also determined, and upon the margin of this bulk should be the point longitudinally at which the centre of weight should be located ; that is to say, suppose there were 600 cubic feet of buoyancy between the centre of length and the load-line and the centre of the entire displacement, and that the distance between those points were 13 inches between the two centres, is it not plain that 600 cubic feet of buoyancy must be obtained from that portion aft of the centre of buoyancy ? but it does not follow that the distances will be equal in which it is obtained ; that is to say, it may be found, as most likely it would be, before we went as far aft as 13 inches, but at whatever distance we found the 600 cubic feet at, the after boundary would be the place for the centre of the weight of the engine. In the Plates showing the lines of the ocean steamer, it will be seen that although the $\otimes$ frame is in the centre longitudinally, yet the centre of buoyancy is 4½ feet forward of the longitudinal centre ; as a consequence, the

location of the centre of weight would require to be placed still farther forward, in order to prevent the ship's trimming by the stern. In this case the steamer is small, and consequently has not sufficient length to enable us to make her as sharp as if she were larger, and, as a consequence, longer. Hence we discover that it does not follow, that in adding length to steamships, it must of necessity be equally divided on the ends ; it often occurs that the stern is sharp enough for a speed of 20 miles per hour, while the bow can only be driven 12 to 14 ; this has been proven on our river boats in not a few instances. Hence we say, that if speed is required in ocean steamships, give them length. Suppose 40 feet were added to the bow of the steamer shown in Plate 2, and 10 feet to the stern, and the assumed proportionate power were doubled, may it not be clearly inferred that her speed would be greatly increased ? and we hesitate not to say, that such vessel could go to Liverpool within 8 days instead of 10½, as we now do. But an objection may be raised to her want of depth, and, as a consequence, a want of sufficient strength. If this supposed want of depth were absolutely necessary for strength, it would be a tenable position ; but inasmuch as the required strength can be furnished without our being

burdened with extra depth, we would add, that she has a proportionate amount ; and it is presumable that the addition assumed would be sufficiently buoyant to carry its own weight, and, doubtless, something more ; consequently, the draught of water would call for no more depth of hold, and any extra top hamper would only serve to make the ship roll. We have not taken the position of assuming that the lines of the steamer shown in this work was not sharp enough ; we only say, that if a greater speed is required, she would be too small. Without doubt she is sharper than any vessel of her class now built, and for her size is perhaps about sharp enough ; she could not, however, be made much sharper without increasing the length. With regard to the strength of ocean steamships, they cannot be made too strong. Of the manner now almost universally adopted of cross-plating the frame on the inside, too much can scarcely be said in its favor. Some, however, have supposed that the single plate was enough—that there was danger of a collapse by adding the cross-plate, even though they were rivetted together at the crossings—those apprehensive fears are groundless ; the strength depends somewhat upon the size of the plates, and their number plates, one inch thick by 5 inches wide, is quite light enough

for a steamer of any considerable size. The first course is usually let into the frame at an angle, with a vertical position of the frame of 45 degrees, and the second course runs in the opposite direction, at the same angle—all being sufficiently bolted to the frame, and rivetted together at the crossing, (which must come in the room between the timbers,) renders the whole fabric strong longitudinally. The most ready manner of obtaining the marks for the holes, is to take a rule staff about the width of the plates, and bend it out to the place where the plate belongs, and mark the holes upon it, transferring the same to the plate. But there are other and additional means by which strength may be added to steam-ships ; they may have iron clamps, which would be both stronger and lighter than the same of wood. We may also have iron keelsons made of sheets of boiler iron, bolted on the sides of the centre keelson, which would take no room worth speaking of, and could easily be prevented from corrosion and rot, consequent upon the action of heat and salt to which they would be exposed ; and as far as speed and strength are entitled to notice only, an iron steam-ship could be made both stronger and yet lighter, assuming two vessels to be built by the same model, the one of iron and the other of wood ; hence we

say, for speed iron is preferable to wood. The corrosive qualities, as we have before said, is a barrier against its use for the outside shell, but may be used inside, as we have described, with great advantage.

With regard to the power of steamships, we deem it important that we should make some remarks. Many persons have supposed that if the vessel were made sharper, less power would answer all purposes. This is a great mistake; it is the place, and the only place, where its advantages may be seen. A large amount of power applied on a full vessel is thrown away. True, it causes the ship to make much disturbance; it causes an amount of resistance equal to the power of the engine, but this is not speed. We might rend the vessel into fragments with the power applied, and she would not be fast; she has a column of water to raise in length equal to the length of the voyage, and in breadth equal to the breadth of the wave her fullness generates, and its depth is equal to the altitude of the wave. Now it must appear quite clear, that inasmuch as resistance increases so much faster than power when an attempt is made to increase the speed of vessels, whether by steam or sail, that it were a fruitless task to endeavor to remove this column of water fast; thus we say,

power is thrown away on full vessels, beyond that which is required for a speed adapted to, or commensurate with, the shape; and if a man is so unfortunate as to own a full steamer, he should be content with moderate speed, or he may be compelled to abide by the results we have shown, after having spent much money to reverse it. And when we have a sharp steamer, the power is required to bring her fully up to an amount of resistance commensurate with the shape, inasmuch as it is assumed that this vessel is meeting the resistance on the sides of the bow and not at its commencement; hence it is quite manifest that the application of power must increase the speed in a greater ratio on the sharp vessel than on the full one, from this fact, that the steamboat of 10 miles per hour makes more disturbance than the boat of 20 miles per hour. We seem, however, to forget, that inasmuch as the resistance is less on the sharp vessel, it should be greater at the wheel to be equal to the vessel of more moderate speed; and that as the ocean steamer must have a very considerable dip, (else the wheel will be out of water at times,) and that this increased dip requires an enormous amount of power to turn the wheel sufficiently fast to bring the ship up to her required resistance; we make use

of this term because we wish to be understood in this matter to say, that an ocean steam-ship (if she is very sharp) requires a considerable amount of resistance on the bow to keep her steady ; it is like wedging the bow fast that it cannot veer about, and we will add, that she will perform better, and if the bow is properly formed, will prove herself to be a better sea boat in every respect. This leads us to another consideration : the wheel must be larger, or must turn faster ; but to the latter there is this objection : the heavy machinery required for ocean steamers cannot, without hazard, be made to move as fast as that of the river boats ; hence we find ourselves deficient in power ; and if we increase the size of the wheel and secure a larger dip, we cannot turn the wheel fast enough ; and although steam-ships have less stroke than steamboats, they have cylinders of much greater diameter, and require more steam, having two engines ; more particularly if they have reserve power. Hence we say that it amounts to this : the full steamer is strained by undertaking to force her beyond her appropriate speed ; while, on the other hand, if she is very sharp, and this sharpness is of the right kind, it binds her together, and keeps her steady, and the ship would perform better in every respect by being driven with extra or re-

serve power ; and the same is equally true with very sharp sailing vessels that have great length, if their propelling power is properly distributed.

This seemingly paradox may be illustrated in the following manner : when a sailing ship has the wind directly ahead, she cannot prosecute her voyage in its proper direction, but must turn aside until the wind is received partly in the direction of the beam, and the impulsive power aft of the beam, or at right angles with the line of direction from which it comes ; if the ship be full, and a press of sail is crowded upon her, she is almost brought to a stand still at times by the power of the sea ; the surges are felt all over the ship, and the area of sail spread may be increased, but the ship will go no faster ; she may labor more, surge heavier, or plunge deeper, but go no faster. Let this same ship be made sharper by lengthening the bow from its after part and continuing forward any given distance, say as far as the front of the cut-water from 10 to 12 feet ; let the ship be again placed in the same circumstances as before, and we shall find that she sails faster with the same sails set as before, and that she makes less disturbance on the bow ; but notwithstanding this, we shall also find that more sail would be an advantage in making her motions

regular; the vessel would be dry, (provided the bow were properly shaped,) and sail faster; hence we say, that every vessel (and steamers in particular) require when sailing or steaming, an amount of resistance commensurate with the shape; this is obtained by the application of power, whether secured from the leverage of the masts or the rotary motion of the water-wheel; and it may be set down as an axiom, that under ordinary circumstances a diminished resistance on the immersed part of the hull demands an increase of power to secure the contemplated speed.

There have been some steam-ships built in the United States that have attained a tolerable degree of speed; among these none stand more conspicuous than that of the steam-ship Georgia—the tables of which has found a place in this work. In contrasting the advantages of a proportionate breadth for steam-ships, we have had occasion to notice this ship, on page 106, and deem it only necessary to add, that she has had less alterations and repairs than any other American steamer that has been built; and although she has her greatest displacement aft of the longitudinal centre of length, and, consequently, the small end (and as many have thought and said the wrong end) ahead, she has

run 1000 miles within 60 consecutive hours, which is equal to 400 miles per day. This ship, on her first voyage, was trimmed by the head, under the supposition that her fullest end being aft, she would require to be by the head to make her steer, but this was found to be an error; her sailing trim being 3 inches by the stern, and when in this trim there is no difficulty in steering or working the ship; her mean load-line draught of water is 16 feet, which is about all that can be made available in running to New-Orleans, to which route she is remarkably well adapted; and notwithstanding her light draught of water compared with her tonnage, which is equal to that of the largest that has been built in this country, we have the highest rate of speed that has been attained by steam-ships, with only about 4-5ths of the power of those crossing the Atlantic. She is well adapted for navigating one of the most dangerous coasts laid down on any chart. The proportionate dimensions shown on page 43, are carried out in the construction of this ship; and if farther illustrations of the advantages of beam were required, we are here furnished with them. The area of her greatest immersed transverse section equals 677 square feet; her launching draught was 7 feet 9 inches; her constructed

TABLES OF STEAMER GEORGIA, FINISHED 1850.

PLAN	FIRST HEIGHT AT 4th Water Line.		FOURTH HEIGHT AT 4th Water Line.		FIFTH HEIGHT AT 4th Water Line.		HALF BREADTH AT 1st Water Line.		HALF BREADTH AT 2d Water Line.		HALF BREADTH AT 3d Water Line.		HALF BREADTH AT 4th Water Line.		FIRST BREADTH		SECOND BREADTH		THIRD BREADTH		FOURTH BREADTH		FIFTH BREADTH.	
	ft.	in.	ft.	in.	ft.	in.	ft.	in.	ft.	in.	ft.	in.	ft.	in.	ft.	in.	ft.	in.	ft.	in.	ft.	in.	ft.	in.
4	9	1 4	17	9 5	21	3 2	4	4 5	6	9 5	10	1 1	5	10 7	9	1 4	10	6 3	11	11 3	14	1 2	17	5 5
8	8	5 1	17	1 0	20	7 12	4	2 4	6	3 1	7	8 3	9	6 2	12	3 5	13	8 4	15	0 4	16	11 5	19	6 6
12	7	9 3	16	6 0	20	0 4	6	6 2	10	10 0	10	6 1	11	11 6	15	0 0	16	3 5	17	6 12	19	1 7	21	1 1
16	7	3 0	15	11 3	19	6 2	8	3 3	11	4 3	13	3 3	14	8 2	17	4 4	18	5 5	19	5 4	20	9 1	22	0 4
20	6	9 2	15	5 6	19	0 6	10	4 3	13	9 0	15	8 1	17	2 1	19	3 4	20	1 3	20	9 7	21	8 2	22	8 0
24	6	4 2	16	0 6	18	7 6	12	4 4	15	10 7	17	9 7	19	2 3	20	10 0	21	5 2	21	11 0	22	5 6	23	0 7
32	6	0 0	14	8 4	18	3 4	14	2 6	17	9 6	19	7 1	20	3 5	22	0 3	22	5 5	22	9 0	23	0 5	23	4 1
36	5	8 4	14	4 7	17	11 7	15	10 2	19	5 3	21	0 0	22	12	0 0	22	10 4	23	1 6	23	3 4	23	5 1	
40	5	5 7	14	2 3	17	9 2	17	3 4	20	8 4	22	1 4	23	11 0	23	5 5	23	6 6	23	8 0	23	7 0	23	6 6
44	5	5 4 1	14	0 5	17	7 6	18	1 12	21	7 2	22	10 5	23	6 0	23	0 7	23	10 0	23	9 4	23	8 2	23	6 5
48	5	5 3 1	13	11 0	17	6 8	18	7 4	22	1 5	23	4 0	23	9 3	23	11 5	23	11 3	23	10 4	23	6 6	23	6 2
52	5	5 2 5	13	11 0	17	5 6	18	8 2	22	3 0	23	5 2	23	10 4	24	0 0	23	11 3	23	10 2	23	8 2	23	5 0
56	5	5 2 5	13	11 0	17	5 6	18	2 2 0	21	11 0	23	2 5	23	9 0	23	10 5	23	10 3	23	9 1	23	6 7	23	3 0
60	5	5 3 2	13	11 2	17	6 2	17	0 0	21	1 4	22	7 4	23	4 0	23	7 4	23	7 4	23	6 3	23	3 7	23	11 5
64	5	5 4 4	14	0 0	17	6 6	16	3 0	19	10 3	21	9 0	22	8 6	23	2 6	23	8 2	23	12 12	23	11 6	23	7 3
68	5	5 6 4	14	1 0	17	7 2	13	0 7	18	1 4	20	6 2	21	10 2	22	8 4	22	9 5	22	8 7	22	6 5	22	2 2
72	5	5 9 0	14	2 6	17	8 4	10	6 7	15	9 5	18	9 4	20	7 5	22	0 0	22	2 5	22	2 6	22	1 0	21	8 5
76	6	6 0 2	14	5 1	17	9 5	7	10 7	12	11 4	16	4 4	18	10 4	21	0 4	21	5 6	21	7 3	21	6 0	21	1 7
80	6	6 4 1	14	8 1	18	0 0	5	4 1	9	8 0	16	1 6	16	2 4	19	8 3	20	6 0	20	9 2	20	9 1	20	5 5
84	6	6 8 7	14	11 4	18	2 4	8	1 0	10	2 0	9	1 2	12	3 0	17	8 4	19	1 6	19	8 0	19	9 4	19	7 4
88	7	7 2 6	15	3 5	18	6 0	1	4 0	2	10 0	4	6 0	6	10 0	14	2 4	17	2 5	18	0 1	18	6 4	18	7 0
92	7	7 6 2	16	6 0	18	7 7	0	8 0	1	4 0	2	2 0	3	6 0	11	2 0	15	5 1	16	8 5	17	7 4	17	10 6
96	7	7 10 4	16	8 4	18	10 0	.....	.....	.....	.....	.....	.....	.....	.....	5	5 0	12	5 1	14	8 6	16	3 1	16	11 1
100	.....	.....	15	11 3	19	0 3	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	10	4 4	13	7 0	15	1 4
104	.....	.....	16	0 5	19	1 6	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	10	10 0	13	4 0
108	.....	.....	16	2 0	19	3 6	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
112	.....	.....	18	5 6	21	11 3	0	10 5	1	6 1	2	1 5	2	9 5	5	6 2	6	9 6	9	2 5	10	6 0	14	4 0
116	.....	.....	18	10 1	22	3 4	.....	.....	0	5 4	0	10 2	1	3 6	3	7 0	4	10 2	6	1 3	8	4 3	12	4 4
120	.....	.....	19	1 6	22	8 2	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
124	.....	.....	19	7 5	23	1 0	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
128	.....	.....	20	0 4	23	5 4	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
132	.....	.....	23	10 3	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
136	.....	.....	24	3 6	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....

RAKE OF STEM FROM FRAME D.

On first Water Line.....	2	6	0
On second Water Line.....	5	6	7
On third Water Line.....	7	2	1
On fourth Water Line.....	8	7	4
On first Height.....	13	9	0
On second Height.....	16	0	0
On fourth Height.....	22	8	0
On fifth Height.....	31	8	0
5 ft. 10 in. above fourth Water Line.....	10	11	6

Second Height is 3 ft. above the first.
Third Height is 2 ft. 6 in. above the second.
Second Height on Stern is 14 ft. 4 in.

Second Height on Stern is 11 ft. 3 in.
Rib of Stem at Frame 4 rises $\frac{1}{2}$ in. at Frame $\oplus$, 10 in. at Frame D, rises 2 ft. $\frac{1}{2}$ in. at Frame E.

Rake of Stern Post at fourth Water Line.....	2	3	3
first Height.....	4	11	4
second Height.....	7	8	5
fourth Height.....	12	6	5
fifth Height.....	14	1	6
Heel of Post aft of Frame 62.....	2	7	2
First Water Line above Base.....	2	0	0
Second " " " first.....	8	10	0
Third " " " second.....	3	10	0
Fourth " " " third.....	3	10	0
Timber room and Space.....	2	7	0

Frame 43 and 44—2 ft. 9 in.

load-line of flotation furnished a draught of 15 feet 6 inches (which contemplates her without freight) water, below which her displacement is 2700 tons 592 pounds.

With regard to steam-ships for speed, they should be large; there is scarcely a limitable length beyond which steam-ships cannot go, provided they combine strength in proportion to the increased size, which we are fully satisfied they may. We believe there is much room for improvement in the marine steam-engine; likewise in the water-wheel; and while ship-builders are perfecting the hull, the engineer should be endeavoring to rid the engine of the enormous amount of friction, by more direct application.

Among the different channels through which the commercial intercourse of our country is augmented, the coasting trade of the United States is not the most insignificant. Perhaps there is no coast on the globe of the same extent that has so much demand for vessels of easy draught of water. Almost the entire southern coast of the United States is linked to the ocean by shoal rivers; hence it is plain that the vessels engaged in our coasting trade should be so constructed that they may be able to ascend those rivers to the various ports of entry located thereon. The proportionate dimensions of coast-

ing vessels will be found to differ widely from those of sailing ships. It is not unfrequently the case that schooners are built with a breadth of 3 times the depth; and we have known schooners that have had a breadth of half of the length of keel; they, however, had great rake, both to the stem and stern-post.

The coasting vessels of the United States combine the greatest variety of shape and principal dimensions; and we would doubtless be quite safe in our conclusions were we to add, to a much greater extent than in any other part of the world, which we think the difference in the draught of water will fully prove. There are vessels built of considerable size that run on a draught of 3 feet, and from this extraordinary light draught up to 10 feet water; they are doubtless the most stable vessels in the world, because of their great breadth. It must be quite apparent that no definite instruction can be given for the construction of coasting vessels that will apply universally to all, inasmuch as some are built with a centre-board, or moveable keel, to increase the lateral resistance when the water is of sufficient depth to admit of its being lowered, while others have a deep keel; and again on the other hand, some have no centre-board and a very small keel; and although very many

persons are firm in the belief that a vessel must have a sharp floor vertically, in order that she may sail fast, yet we sometimes see a vessel that is perfectly flat having a centre-board, and sailing faster than another vessel having a very considerable vertical rise; hence we are brought to this conclusion, that it is in the shape more than in the vertical rise that properties of speed consist. This, however, is quite conclusive, that the shape must be to a very great extent consequent upon the draught of water, inasmuch as the fact is too palpably plain to be for a moment questioned, that where the draught is very light, or even moderately so, the bow must not be sharp longitudinally, else we shall doubly fail in accomplishing our object; first, we shall draw too much water, and in the next place we shall have an unprofitable vessel. While we are desirous to secure speed, it must not be at the expense of cargo to any very great extent, inasmuch as the most profitable vessels are those which carry the greatest number of tons or barrels in proportion to their tonnage, and also carry them in the shortest possible time, and with the least wear and tear to the vessel, this is the great and most desirable object in coasting vessels.

The tables on page 349 represent a

vessel adapted for the coasting trade, of about 10 feet draught of water, that would be adapted to the schooner rig; she would require no centre-board, having 10 degrees rise to her floor, and having a very considerable length of 104 feet on load-line, with 26 feet of moulded breadth, and the greatest transverse section in the longitudinal centre of length; the lines being easy, consequent upon their unusual length, would render her a profitable as well as a fast sailing vessel, and well adapted to the coasting trade, where that draught of water may be had; she may be very properly termed a high-decked vessel, inasmuch as she is deeper than the proportions of a low-decked vessel would require. We mean by the denominations of high and low deck, a certain adaptation that low-decked vessels have for carrying a deck-load of such articles as are not perishable, they are shoaler than high-decked vessels, and the scantling or moulding size of their stanchions are generally larger, as also their deck-frame; they are principally built for and engaged in the lumber trade, and not unfrequently carry from one-half to five-eighths of their cargo on deck. Almost the whole amount of yellow pine timber brought from the south is carried in this kind of vessel; the timber that is in the log and of any considerable length, say 55

TABLES OF SCHOONER.

DIMENSIONS—LENGTH, 105 feet; BREADTH, 26 feet; DEPTH, from Base line to lower side of Plank sheer, 10 ft. 3 $\frac{1}{2}$ in.

PLANK	FIRST HEIGHT ABOVE 5th Water Line.	SECOND HEIGHT ABOVE 5th Water Line.	HALF BREADTH AT 1st Water Line.	HALF BREADTH AT 2d Water Line.	HALF BREADTH AT 3d Water Line.	HALF BREADTH AT 4th Water Line.	HALF BREADTH AT 5th Water Line.	AT FIRST BREADTH	AT RAIL
	feet.	feet.	feet.	feet.	feet.	feet.	feet.	feet.	feet.
Stem	3.94	6.06	....	....	....	....	....	....	....
L	3.58	5.75	....	1.07	1.5	2.24	2.42	6.42	8.7
Y	3.06	5.61	2.56	4.08	5.5	6.92	8.42	10.68	11.79
U	2.62	4.56	4.96	7.1	8.84	10.17	11.11	12.10	12.68
Q	2.26	4.4	6.75	9.31	10.79	11.75	12.27	12.74	12.79
M	1.98	4.37	8.46	10.8	12	12.62	12.92	12.77	12.83
H	1.7	4.17	9.5	11.79	12.72	13.02	13.08	13.07	12.75
D	1.52	4.05	10.67	12.35	12.98	13.18	13.19	13.04	12.66
4	1.46	3.92	10.23	12.42	12.99	13.17	13.17	13.	12.5
8	1.43	3.79	9.87	12.17	12.77	12.99	13.	12.91	12.81
12	1.46	3.68	9	11.5	12.8	12.62	12.66	12.68	12.66
16	1.63	3.96	7.56	10.33	11.68	12.07	12.25	12.28	11.74
20	1.64	4.05	6.79	8.58	10.39	11.28	11.74	11.75	11.87
24	1.83	4.12	3.92	6.27	8.42	9.99	10.65	11.1	10.92
28	2.07	4.31	2.14	3.66	6.45	7.64	9.33	10.35	10.31
Stem	2.23	4.56	.78	1.17	1.69	2.62	4.42	9.06	9.55
		4.85	....	....	....	....	....	7.92	8.87

RAKE OF STEM FROM FRAME b.

On first Water Line.....	1.08
On second Water Line.....	1.87
On third Water Line.....	2.4
On fourth Water Line.....	2.75
On fifth Water Line.....	3.11
On first Height.....	4.16
On Rail.....	5.
Rise of Stem at Frame b.....	.71

Floor straight—8 feet out from centre.

RAKE OF POST AFT OF 23.

On Base.....	2.76
On fifth Water Line.....	3.04
On first Height at centre.....	4.33
On Rail at centre.....	6.
Cross Scam above fifth Water Line.....	1.25
Frames apart.....	1.75
Water Lines apart.....	1.76
Dead Rise, 10 degrees.	

TABLES OF PILOT-BOAT MARY TAYLOR.

HEIGHT OF GUNWALL ABOVE the Water Line.		HALF BREADTH AT Gunwale.		HALF BREADTH AT 1st Water Line.		HALF BREADTH AT 2d Water Line.		HALF BREADTH AT 3d Water Line.		HALF BREADTH AT 4th Water Line.		RISE OF MARGIN LINE ABOVE Base.	
Frames.	Feet.	Frames.	Feet.	Frames.	Feet.	Frames.	Feet.	Frames.	Feet.	Frames.	Feet.	Frames.	Feet.
Stem	2.96	2.....	2.21	2.....	.....	2.....	.35	2.....	.79	2.....	1.25	Stem	6.65
2.....	2.54	4.....	3.83	4.....	.27	4.....	1.02	4.....	1.87	4.....	2.73	2.....	5.64
4.....	2.08	6.....	5.25	6.....	.69	6.....	1.90	6.....	3.17	6.....	4.29	4.....	4.58
6.....	1.77	8.....	6.83	8.....	1.29	8.....	2.92	8.....	4.52	8.....	5.77	6.....	3.94
8.....	1.5	10.....	7.66	10.....	2.03	10.....	4.	10.....	5.89	10.....	6.97	8.....	1.5
12.....	1.04	12.....	8.29	12.....	2.83	12.....	5.1	12.....	7.04	12.....	7.78	10.....	3.1
16.....	.81	16.....	8.46	14.....	3.60	14.....	6.1	14.....	7.08	14.....	8.25	12.....	2.84
20.....	.75	20.....	8.29	16.....	4.31	16.....	8.95	16.....	8.48	16.....	8.55	14.....	2.78
24.....	.79	24.....	7.87	18.....	4.89	18.....	7.53	18.....	8.75	18.....	8.76	16.....	2.53
28.....	.96	28.....	7.29	20.....	5.25	20.....	7.83	20.....	8.83	20.....	8.81	18.....	2.1
32.....	1.29	32.....	6.5	22.....	5.86	22.....	7.87	22.....	8.76	22.....	8.75	20.....	1.86
36.....	1.52	Post.....	6.29	24.....	5.25	24.....	7.66	24.....	8.62	24.....	8.62	22.....	1.66
Post.....	1.96			26.....	4.78	26.....	7.11	26.....	8.42	26.....	8.46	24.....	1.43
Stem	3.25			28.....	4.06	28.....	6.29	28.....	8.06	28.....	8.28	26.....	1.21
				30.....	3.06	30.....	5.11	30.....	7.28	30.....	8.04	28.....	1.
				32.....	1.86	32.....	3.5	32.....	5.96	32.....	7.64	30.....	.8
				34.....	.9	34.....	1.73	34.....	8.77	34.....	6.87	32.....	.56
				36.....	.4	36.....	.46	36.....	.79	36.....	4.57	34.....	.45
				Post.....	.29	Post.....	.29	Post.....	.29	Post.....	2.55	36.....	.16

RAKE OF STEM FROM FRAME 2.

At Gunwale	Feet.
At fourth Water Line.....	3.33
At third Water Line.....	2.77
At second Water Line.....	1.16

HEIGHT OF WATER LINE ABOVE BASE.

First Water Line at Post.....	4.42
First Water Line at Stem	4.65
Second Water Line at Post.....	5.90
Second Water Line at Stem	6.25
Third Water Line at Post.....	7.35
Third Water Line at Stem.....	7.70

Timbering Room.....	Feet.
Stem aft of Frame 36	4.00

MOULDED SIZE OF STEM AND KEEL.

At Stem-head	.7
At Frame 1	1.17
At Frame 7	1.46
At Frame 21	2.
At Frame 24	2.
At Frame 36.....	2

to 75 feet, is carried on deck, while the shorter lengths are taken in the hold through a lumber port cut through the bow immediately below the deck; this class of vessels are built principally in the New-England States, and although they are profitable, and seem to answer the object for which they are built, yet they have at least one prominent defect—being too low on the bow; the deck forward should be high enough to allow the port to remain above water, until the hold is entirely full. It is not unfrequently the case, that after removing anchors, cables, &c., on the quarter deck to keep the port above water, it is found necessary to close it before the hold is full; the consequence is, the deck must carry the remainder, even though it be the largest half; hence one of the reasons why they are sometimes wrecked.

The famous Baltimore Clipper, of which so many legends have been written, the canvas of which has whitened every sea, has no longer a charm among the owners of coasting vessels; the competition in the coasting trade renders a more profitable vessel desirable, inasmuch as they carry a proportionately small amount of cargo, and do not sail as much faster than other vessels as would make up the defect; another reason for their gradual disuse is found in the fact, that

the slave trade on the coast of Africa is not as prolific as formerly, and their great draught of water shuts them off from their own coasting trade; hence we at once discover that vessels drawing less water, sailing equally as fast, and carrying from 30 to 50 per cent. more in proportion to their tonnage, are much better vessels for the coasting trade of the United States. The tables we have referred to would furnish a vessel of this description.

It should not be forgotten that the tonnage laws have no warping influence on this class of vessels; there is nothing to be gained by disproportionate principal dimensions, as the laws for determining the tonnage of vessels having but one deck, measure the depth of the vessel, and not assume her depth to be about what it ought to be, regardless of what it is.

The centre-board, or centre slide-keel to which we have alluded, has proved itself to be of great advantage to vessels of light draught, inasmuch as they are sometimes in deep water, when it can be lowered or dropped down to enable the vessel to hold a better wind, or to sail by the wind with less lee way. The slide keel is usually placed above the middle of the vessel longitudinally, and varies in length according to the size of the vessel, from 15 to 20 feet long; the trunk or well

that contains and protects the board, and at the same time keeps the water out of the vessel's hold, is usually cut through the vessel at the side of the keel; the smaller sized craft have the trunk through the middle of the keel; it is framed by placing a stanchion at each end of the trunk, which extends quite through the frames, and as high as the top of the deck; the size must be sufficient in the transverse direction to form the opening for the board, but to this may be added the thickness of the plank with which the trunk is to be planked on both sides; in the fore and aft direction, the stanchion should be large enough to receive all the fastening the trunk will require; the frames which are thus cut off, box into a piece of timber placed along side of the keel, and extending below far enough to come flush with the bottom plank, and above high enough to bring the first seam of the trunk above the ceiling; the length of this side keel should be sufficient to cover several of the frames, both forward and aft of the trunk; thus it will be perceived that there is no seam in the well of the trunk that cannot be readily caulked; this job should be well done, inasmuch as this kind of vessel has suffered severely in their reputation in consequence of leaky trunks. It cannot be denied that they are less strong than other

vessels that have their frames entire; but if proper care is taken, and the short frames properly secured by an extra side keelson and knee'd to the trunk, they are sufficiently strong for navigating our rivers, and in some cases our sea-board, where many are now engaged. The board is usually hung by a single bolt at the forward end, about $\frac{1}{3}$ of the breadth of the board from the lower edge, and at such distance from the forward end as to admit of the exposure of $\frac{1}{3}$ of the board below the bottom of the keel; being thus hung, it will be perceived that when the edge of the board strikes the bottom of the river in shoal water, it will rise without damage to the vessel; and having a small chain appended to the upper edge of the board at the after end, it is readily raised by a small winch placed on deck at the after end of the trunk for that purpose.

It must be quite apparent, even to the casual observer, that with a large lever extending quite through the vessel, and a number of feet below, acting in the one direction, and with another in the masts, extending many feet above the deck, acting in the opposite direction, must have a very powerful tendency to divide the vessel into two parts; hence we say, that extraordinary means are required to secure the vessel against this dividing tendency;

and an extra amount of timber and fastening are required to secure centre-board vessels from consequent leakage upon any neglect in this particular. In small vessels there are many parts where screw-bolts should be used in lieu of blunt bolts, or those that are riveted; the size of the bolts, both in diameter and length, or the small amount of surface presented by the reduced size of the timber, renders it necessary that the bolt should possess more of the confining property than its surface on the sides alone presents; and in addition to this, bolts in small timber are seldom driven harder than it is found to be perfectly safe to drive screw-bolts, and yet possess all the drawing properties peculiar to the screw. With regard to the form of the lines of this class of vessels, it has been found that inasmuch as the very light draught they are required to draw presents such formation as would divide the fluid very different from another vessel of heavier draught; in this case the fluid must be parted in a diagonal direction on the bow, and the parallel lines to that of flotation require to be very round, with a very considerable rake to the margin line of the stem; thus it will be perceived that the vessel slides partially over the fluid, rather than part it in a horizontal direction; the lines aft require to be quite hollow near the extremities, else the great breadth of the buttocks would prevent the retiring molecules from reaching the rudder before the strength of the current, caused by the moving vessel, had partially subsided. That a vessel's motions under some circumstances would be easier by having some dead-rise, there can be but little doubt; and we will add, that an easier angle of resistance may also be obtained on the vessel having some vertical rise; and all vessels that are propelled by sails having no centre-board, should have some dead-rise to the floor, for the following reasons: the bilge should not hang below the keel, which it undoubtedly would (when the wind was not directly aft) were there no dead-rise. If we have more than a sufficiency for this, which should seldom exceed 10 degrees (unless the vessel be a yacht or a pilot-boat) where every other consideration is sacrificed for sea qualities, and in such case 15 degrees would be as much as we could derive advantage from. This fact should not be forgotten in modelling sailing vessels, viz., that by giving the vessel a large amount of dead-rise, we undermine the foundation for carrying sail, and cause the vessel to heel or incline from her vertical and proper position for speed more than she otherwise would. In a river where (with a head



wind,) the sloop or schooner with perfectly flat bottom and centre-board is often found to outsail the pilot-boat, the reason will appear obvious: the sloop with her board partially or entirely out presents much greater lateral resistance, because she heels or inclines less; and farther, the sides of the board are vertical when the vessel is upright, while the bottom of the other on the lee side presents a plane parallel, or nearly so, to the surface, and the keel, from its inclination, does much less toward holding the vessel to windward than an equal amount of surface on the centre-board does. Hence we discover that the sloop is enabled to carry a greater amount of sail, and at the same time makes less lee way, and need not tack as often; but again, the great breadth of the sloop furnishes her with very round side lines, and completely divests her of the straight or partially straight side that we have so fully deprecated in the preceding pages of this work; those round lines incline her to come to the wind, when the smallest impulse at the helm favors this course. This inequality of the two lines of flotation, although it causes all vessels to carry a weather helm, or compels the helmsman to keep his tiller to windward, is a bane in all, and more particularly in sea-going vessels, on account of the increased submer-

sion caused by the sea, and of the comparatively straight side-line that this class of vessels usually possesses; in vessels of light draught it cannot be avoided, without the sacrifice of other equally important qualities. We have said that this round side-line enabled the sloop or schooner to come into the wind quick, and in this respect she would have the advantage of the pilot-boat or other vertically sharp vessel; not only so, but by having more bilge; more side surface is presented, which augments the rotundity we have appreciated for working quick. But again, it may be said the flat surface is also increased that has been repudiated. To this we in reply would only say, that the flat is increased transversely, but need not be longitudinally, inasmuch as the lines of resistance on the flat vessel run more nearly in the direction of section lines, while on the sharper vessel they run in the direction of diagonal lines; they may each alike be divested of the straight as soon as we fairly get clear of the influence of the base-line; the transversely flat bottom we have shown is an advantage for stability.

It must not be inferred from what has been shown that the vessels engaged in river navigation are entirely free from discrepancies; but we feel quite safe in the assertion, that they









are much better adapted to the objects for which they are designed than sea-going vessels. We think that science alone cannot very materially add to the improvements in this class of vessels; there is, however, a slight discrepancy perceptible on some of the finest and fastest sloops on the Hudson river; the greatest breadth on the stern and quarter should be at the gunwale; this would enable the builder to more nearly equalize the two lines of flotation; the loss of buoyancy would be unworthy of being brought into the account, inasmuch as it would be above the load-line of flotation; and no matter in what light we may look at it, except that of appearance, it will be an advantage, and as for beauty, we have already defined it to be, fitness for purpose and proportion to effect the object designed.

It may be supposed, and reasonably so, that at sea the vertically sharp vessel, the pilot-boat for example, would prove not only the best sea vessel, but the fastest; and the reason we think will be quite clear, when we remember that the pilot-boat is parting the water, while the flat sloop or schooner is sliding over it, and the consequent round bow is continually brought in contact with the waves, unless the wind were directly aft, and then the chances would be more equal;

but under any circumstances, the two kinds of vessels each work best in the element for which they were designed. We have seen flat centre-board vessels at sea that performed well, but it cannot be expected that they should be as free from straining as the longitudinally sharper vessel; they must of necessity be full on the bow, which presents a surface for the sea to strike against, which not only retards the progress, but strains the vessel. We have shown on Plate 24 the lines of a pilot-boat now building, to be called the *Moses H. Grinnell*, and it may reasonably be inferred that she will prove to be the finest vessel of her class in the United States, (and although it is usual, and but fair to add, of her length;) we would hardly confine the competing vessel to an equal length on the load-line of flotation, if she be now built or building. This vessel, built by a model not unlike that of the *Mary Taylor*, a pilot-boat designed and built by the same builder, Mr. George Steers of this city, is altogether different from those stereotyped shapes that may be seen skirting the coast off the principal sea ports. The *Mary Taylor* has surpassed the expectation of her owners, and even of the sanguine builder himself, and may justly be styled the model craft for this kind or description of vessel, the tables of which will be found on page 350.

Plate 25 furnishes the lines of the sloop Victorine, which plies on the waters of the Hudson, and is said to be the fastest vessel of this description on that river, of which there are not a few. This vessel was built at Piermont, a small town on the Hudson, about 24 miles above this city, by Jno. J. & Caleb H. Wilsie, and fully carries out our remarks in relation to the requirements of this description of vessel; she has a centre lee-board, as shown on the draft. Vessels of this class or description form a very considerable part of the domestic commerce of the United States, and bear a strong resemblance in their principal dimensions and rig to the English cutter; although the shape differs in some particulars, yet there is a kind of sameness in the appearance of both, with this exception: the cutter has no *stay* to support the jib; the mast and bowsprit are shorter in the cutter than in the sloop. They are found to be the most servicable kind of sailing vessel that has ever navigated the Hudson and East rivers, many of which are engaged in the transportation of brick. They have a brake in the deck line in about half its length, or somewhat aft, and have a bulk-head across the entire main deck; the quarter deck is raised for the purpose of furnishing cabin room. Their great breadth enables them to carry enormous deck loads; the round of their deck transversely exceeds that of any other kind of vessel—often exceeding 12 inches in 26 feet.



the appearance of the sails, and the manner the cutter has in sea, and the way the men and the boat are situated in the entire phenomenon. They are found to be the most serviceable kind of sailing boat that has ever navigated the coast and fast rivers, many of which are employed to the transportation of the inland trade in brick. They have a rake in the deck of about one degree, and the foremast (half its length) or sometimes two masts, and a boom. I have a bulk-head across the middle of the hull, and the foremast is in the quarter of the hull for the purpose of being raised for the purpose of getting the boat up or down a rapid. Their great bulk-head is in the middle of the hull, and the foremast is in the quarter of the hull. The round of their masts is very much above of any other kind of mast, and the foremast is in the quarter of the hull.



CHAPTER XI.

Vessels of War less complex in their Construction than Merchant Vessels—The United States Navy behind the age—Ships of the Line expensive and inefficient—Frigates and Sloops of War—War Steamers.

The reader will doubtless be not a little surprised at the announcement heading the contents of this chapter, inasmuch as it has always been set down as an axiom that war vessels were much more difficult to construct upon philosophical principles than those of the merchant service; however widely this opinion may have been disseminated, it is not true, as we shall show, and we think conclusively, to the candid thinking mind.

In connection with the subject of a vessel of war, or in the common acceptance of the term, *Man of War*, the mind becomes associated with a degree of perfection unattainable in those of the merchant service; and it is not unreasonable to suppose that it should, being placed as it is under the fostering care of monarchical governments. But in a country like the United States, where the people are the sovereigns, the case is widely different.

It is not our purpose, were it our

province, to enter into a detailed history of the navies, either of the Old or the New World. From the time of *Archimedes*, the great Syracusan philosopher, who built the first ship of any considerable size for the purposes of war, to the induction of ocean steam navigation, there has been a fictitious value set upon the amount of science required to construct this engine of war. That there is much skill required, we readily admit; but that an equal amount of science is displayed in the construction of a ship of the line (or one of less magnitude) with that of a merchant ship, that answers well the object for which she is designed, we unhesitatingly deny. The ship of the line, or seventy-four, as they are sometimes called, floats upon the bosom of the tumultuous wave in accordance with the known laws of displacement, as do all other vessels; and it is only requisite to fix upon a determinate line of flotation, below which there shall be a sufficient displacement to

furnish the required stability and buoyancy to sustain the ship and her equipment; she is required to perform her functions while at this line of flotation, and at this line only, and is so arranged (or should be) that no variation is perceptible from this line of immersion; for while her fresh water is used out of the tanks or casks, they may be filled up with salt water, and thus secure an equal amount of stability and displacement at all times; and the vessel, while she retains her shape and size, is always assumed to have this determinate line of flotation: hence we say, there is but one calculation to make for the vessel. Not so, however, with the merchant ship: she is destined to be laden at every line of flotation, and at the same time be fully adapted to all the requirements of stability, buoyancy, and speed, at one voyage—laden with cotton, and requiring all the ballast in the hold, and perhaps at the return voyage requiring that same amount of ballast in the steerage, having rail-road iron in the hold, while on another voyage no ballast will be required either in the hold or between decks; at every line of flotation the ship must answer all demands, or the builder is at fault; not only so, but the vessel must retain her shape, no matter what the disparity may be in the distribution of her cargo; at one voyage loaded

when but half full, at another full when but half loaded; under all these diversities the spars must be adjusted in such a manner that the leverage will also be equally distributed; the ship must steer and work well at every line of immersion. This universality is confined to freighting ships alone; the inequality in the lines of flotation is a complex question in the merchant ship, inasmuch as it may be equalized with advantage at one line of flotation, and the same arrangement will be deleterious at another; hence we say, that science and practice should be inseparably blended in the construction of merchant ships. The naval constructor would be less successful in the construction of a merchant ship that would accomplish all the purposes for which she was intended, than the private builder; this has been fully proved in the Navy of the United States. The difference lies just here: in the naval service all is assumed to be science, without practice, while in the private service science and practice are blended. It is, however, but recently that its effulgent brilliance has shed sufficient light upon naval affairs to enable the Naval Architect to discover that the propelling power should find its adaptation to the hull through other channels than those denoting the number of guns for which the ship is to be

pierced. A practical builder would never think of sparring two ships alike, because they were of the same principal dimensions, without reference to the model; and yet this has been the stereotyped practice for years in the Navies of both the Old and New World. That it is less difficult to construct vessels for the avowed purposes of war, will appear manifest, if we but consider the objects to be attained; first, the vessel shall possess the necessary quality of being able to carry and work her guns in all weathers; this calls for *stability*, both theoretical and practical; the second essential quality is found in the speed necessary to be attained, for a vessel of war should be fully able to outsail all other vessels, particularly those designed for freighting purposes; and yet the fact is too palpably plain to be for a moment questioned, that the navy is behind the merchant service in point of speed, notwithstanding the many varying circumstances to which the merchant ship is liable, that the war vessel does not encounter. The merchant ship must be built by such dimensions as will enable the owner to gain by her measurement; she must carry more than her tonnage, and as much as other ships, or she is unprofitable; she must be loaded often in a hurry, and without reference to the moments of inertia;

and in addition to this, the builder finds it absolutely necessary to deceive the owner in relation to the dimensions, model or spars, to save himself from the cruel mortification of witnessing in the ship he builds a total failure in some of the most essential qualities, while he is compelled to keep the improvement to himself, and thus feed the vanity of ship owners; and when we remember that the private builder is expected to (and does) improve against this tide of influences that oppose him, we cannot but admit that it is less difficult to construct a war than a merchant ship. The war ship has a determinate cargo, the weight of which is known, and, as a consequence, the centre of gravity of this weight is also known, and the weight can be so distributed as to furnish the most advantageous trim for speed. She is required to carry a sufficiency of provision in addition to her armament for a limited period, and no more—under these favorable circumstances, we see nothing to prevent them from being the fastest sailing ships on the globe; but the contrary, until within a very few years, has been the case.

With regard to requirements necessary to secure the first essential quality in war ships, viz., stability, we say that a good degree of breadth is required, the proportionate amount of which

will, in some degree, depend upon the weight of the battery to be sustained ; if the battery be on more than one deck, the breadth should be $\frac{2}{3}$ that of the depth ; the length should be at least 5 times that of the breadth, and this would only accord with the proportion of some merchant ships. It must not be expected that a ship can be an extraordinary fast sailer without length. The day is not far distant when merchant sailing ships will be built of a length 6 times their breadth, and if war vessels are to sail from 12 to 13 knots by the wind, which they should do, they must be long. Much may be gained by reducing the weight they are now required to carry. It must be apparent to the thinking man, that it is much easier to obtain water than other supplies belonging to the provisioning calendar in foreign ports ; hence we say, that if it is necessary to carry provision for four months, it is not necessary to carry water for more than 2½ to 3 months ; the amount of buoyancy necessary to sustain this extra amount of water may be taken off the model, and thus diminish the resistance, which will enable the ship to sail faster, and, consequently, render her more efficient, inasmuch as a war vessel is little better than a failure, if she does not surpass in speed other sailing vessels. If we should judge of the

feelings of others from what would be our own, were we appointed to a ship that in point of speed was destined to follow in the distance, *chilling indifference* would fill the place that would, under other circumstances, have been filled by *enthusiastic zeal*. The very form and nature of our government calls for an efficient Navy, not formidable by the number of guns heaped upon one vessel, or by the terrific frown of a few ships of the line, that could be taken by a single steamer—ships that are formidable only in fine weather at sea, or to a crippled vessel of the enemy that is unable to maintain her ordinary speed by some casualty. The annals of the Navies, both of the Old and New World, will show how comparatively little service this class of vessels have rendered ; nor indeed is it reasonable to suppose it could be otherwise ; and whatever may be said to the contrary, we say that it would be a wise policy for the United States to *razee* all her ships of the line ; they would be capable of rendering much more efficient service at much less cost. The only reasons that can be adduced (having the least claims to feasibility) why this measure should not be adopted, is found in the fact that other nations have not done so ; thus giving abundant evidence, that in naval operations we are willing to follow,

while every other interest is satisfied with nothing short of the lead. Let us turn our eyes to the history of the Old world, and see what have been the effects consequent upon a formidable Navy, made up principally of ships of the line. That it was the principal cause of the loss of the Spanish Armada of 1588, few will deny. We are told that from the year 1756 to 1760 France had taken from England 2539 vessels; and during the same period England had captured from France 944 vessels; during this time she had 120 ships of the line, all of which were in active service; France had not a single ship of the line at sea—a more conclusive evidence could scarce be adduced of the inefficiency of this class of vessels, inasmuch as it is notorious that English valor was above suspicion, when the terms were equal. Were it necessary, we might show the issues of the present century, with the history of which doubtless our readers are familiar, and need not be repeated. But apart from these, there are other reasons why the construction of ships of the line should be abandoned. We have said that proportion was the rallying watch-word in the construction of ships—not less applicable to naval than to merchant vessels. We find upon applying these proportions to the ship of the line, we cannot secure a sufficiency of stability, and at the same time possess all other desirable qualities; for example, their great height above water, to which must be added the weight of guns above the several decks, rendering it necessary that they should have great breadth; to this, however, there can be no objection, provided it were not absolutely necessary to carry this extra breadth to the extremities, which incapacitates them for even an ordinary amount of speed, and renders them the dullest sailers that navigate the ocean. We have it from no less authority than the officer who commanded one of the best, if not the very best ship of the line belonging to the Navy of the United States, that with a head wind and sea, she could not make more than 6 knots per hour, and she drifted to leeward more than any vessel he ever saw, and at the same time rolled less; this is not the result of observation of a single day, but of a whole cruise of 2 years or more, and furnishes abundant evidence that a full bow cannot sail fast, and that a great draught of water is no security against drifting to leeward, unless the shape be adapted to speed; but admitting that a ship of the line could be so constructed as to make her a fair sailing vessel, and at the same time retain all her efficiency, we say even then it is

an extravagant manner of distributing force upon the high seas; it is true, that the sight of a ship of the line moored before a town or a battery of equal power, is calculated to strike dismay in the ranks of the enemy, but the chances are rare in which the same number of guns placed on the decks of two or three vessels would not accomplish more, even though all this force were required at the same place, apart from the fact that this force may be divided, if necessary. The argument used as a reason why the United States should not abandon the construction of this class of vessels is weak and futile. That a foreign government would treat an ambassador with less dignity on account of his not having been sent out in a ship of the line, is without the slightest foundation, or that the laws of nations would not be as fully respected, or could not be as fully enforced by an equal amount of power distributed on more than one vessel, betrays a want of courage that has never stigmatized the *American* name, either on land or sea. That it is more honorable to move at the slow pace of 6 knots an hour in a ship of the line, than to sail 12 knots an hour under the same circumstances in another ship, is a logic entirely obsolete in any other than naval operations, particularly in this age of advancement.

To make the ship of the line a fast sailer, would be an expensive undertaking, even if it could be accomplished without hazard. But there is another important fact in connection with this subject that should not be brooked in silence; it is absolutely necessary that a ship of the line should draw at least 26 feet of water, (we allude to those of the first class,) and we very much doubt whether there are any belonging to the Navy of the United States that have gone to sea at so light a draught. The height and weight above water require a sufficiency for stowage below, to enable the ship to maintain the equilibrium of stability when a press of sail is spread to the wind, inasmuch as the centre of gravity of the weight above water is high, the centre of gravity of the weight below water should be correspondingly low, else the leverage will be small for carrying sail. With this heavy draught of water the ship is shut out of many important ports, both at home and abroad; there are but three or four ports she could enter in the whole range of coast belonging to the United States, no matter what casualty might occur; this objection alone, were there no other, should be a sufficient reason for abandoning the farther use of this class of vessels.

It may be said with regard to the speed of ships of the line, that they

are only dull when on a wind, or when sailing by the wind; that when the wind is free they sail much better—this we admit, and are willing to admit another fact, viz., that a *Chinese Junk*, or a *scow*, will sail before the wind; the sailing qualities of ships are not determined by the speed with which they can drift in the direction of the wind, but by the excess of propulsion over the resistance presented by the immersed surface. The ships of the line of the United States Navy have an excess of capacity beyond what is actually necessary; they carry too much water for their provisions. It may be said that the excess of water need not be taken, but in answer to this proposed remedy, it may be only necessary to say, that this would lighten the ship above her determinate line of flotation, and, as a consequence, diminish her stability; the only remedy can be found in the first construction: the proportionate draught of water is not at fault—it is the shape; they are fuller than is actually necessary, by an amount of buoyancy equal to this excess; this being entirely impracticable, it only remains to *raze* or relieve them of the spar deck with all its appurtenances, and they will be found to be much more efficient, quite as formidable, and less expensive.

Notwithstanding the British Navy

is at this time more efficient and formidable than perhaps it ever was before, we find but 73 ships of the line on her navy list for 1850, 15 only of which are in commission, and the remainder, 58 in number, are laid up in ordinary; while, as we have shown, in 1760 she had 120 ships of the line, and all in commission. If experience is worth as much to nations as to individuals, our Government might learn something tangible from this; but we need not circumnavigate the globe to show the inefficiency of ships of the line. A line preparatory to action can be formed of other ships than those having two gun decks and a spar deck, that will prove more powerful in the weight, if not in the altitude of their battery. The dimensions of a ship of the line differs but little from the following: 207 feet on the main gun deck; 54 feet beam; and 36½ feet from base-line to the top of the main gun deck beam; thus we find that her proportions are good, when the spar deck is excluded from the depth—having about 3 feet of breadth for 2 of depth; hence we say, that although her shape gives her stability beyond the usual proportion, yet her stability is artificial, inasmuch as her armament has a permanent location, when the ship is in commission. But enough has been furnished upon this subject.

The next class of vessels that demands our attention is that of the Frigate: this description of war vessel exhibits (even to the casual observer) the constituent properties of efficiency. The first conclusion arrived at, is her proportions: her lower deck guns are carried as high as the ship of the line, and her length is seen to advantage, not being absorbed in top hamper, or surplus height. If the past can furnish an index for the future, we feel quite safe in saying, that until within a very few years the Frigates of the Navy of the United States have rendered most efficient service. The term Frigate applies to a ship having one covered gun deck, and carrying more than 28 guns; there are two classes, first and second, and they are designated by the number of guns they carry. Whatever may have a direct connection with the weight of provisions, guns and other equipments, (more strictly speaking) pertains to other branches of the naval service than that of the construction of the hull, inasmuch as the several departments move each in its appropriate sphere; notwithstanding this, the constructor should know the amount of the entire weight to be sustained before he can design a draft having sufficient displacement to sustain (not only this weight, but) the additional weight

of the ship herself; but this is not all, the constructor should be entirely free from the trammeling influences of furnished dimensions; it is only necessary that he should know the weight of the ship with all on board, the dimensions belong properly to him, and on him should the responsibility rest of her performance, or her ability to carry and work her guns in all weather; our Government has been at fault in this particular; her recent course, however, has furnished some indications of a disposition to place the responsibility where it belongs in relation to smaller vessels, and we say if in one, why not in all?

It cannot be expected that the Secretary of the Navy should know (but for a comparatively short period) the present condition of the Navy, or its future wants; his immediate connection with the political organization of the Cabinet forbids more than a superficial knowledge; hence we may reasonably infer that he must have advisory counsel from some source, and we are brought to the threshold of an inquiry, from what department should it emanate? We may perhaps be allowed to say, if the past can furnish an admonition for the future, let all that pertains to the manner and form of construction emanate from the mechanical department of this branch of

the Government. It has been justly remarked by an eminent ship-builder, that he who could not with his own hands make a model, could not design one; and it is notorious, that while the modelling of ships and other vessels belonging to the Navy was in the hands of a board of commissioners, a downward tendency in every essential quality was but too plainly manifest; and had not better councils prevailed, the Navy would ere this have been a foul blot upon our national escutcheon. We are glad to see that a change of measures has effected wonders, and that instead of the miserable failures that succeeded each other in quick succession, the *bureau* system has wrought a salutary change. It cannot, however, be expected, that even under the present system, the Navy of the United States can keep pace with the improvements of this wondrous age. With few exceptions, the Naval Constructors receive most of the knowledge they possess of ship-building from within the walls of a Navy Yard; thus knowledge becomes hereditary, and the apprentice is taught that *science* is the *one thing needful*, and that whatever emanates from another channel is of little consequence. It is thus that habits are formed, which are like bands of iron when once created; and there are few that are thus circumstanced

who do not carry the pressure of these bands down to the loneliness of the tomb. The effects of this course has a most pernicious influence upon *genius* when in the bud of youth.

Operative mechanics having served an apprenticeship in one of the Navy Yards, well know how greatly they felt the need of that knowledge which is obtained only by practice; the small amount of real *science* which they vainly supposed was to be the palladium of success in all future operations, vanished like dew before the sun, and they were left to learn in riper years the very first principles of ship-building. It may be assumed that this is visionary, or that these are exceptions to the general rule; but we ourselves have been taught these lessons, and had we not laid a foundation among the private competing interests of the day, we should have been subject to the mortifying necessity we have described. We have said that *science* without practice was of little avail, and practice alone is also equally dark; but blend them the one with the other, and they furnish a system worthy of the admiration of the finest and most brilliant genius, rising in organized proportions like a new *Cythera* from the enchanted wave.

Let Naval Constructors become divorced from those habits to which they

have been so long wedded, and look at the rapid progress of commercial enterprise, and they will learn that not only Frigates, but even their Corvettes and Sloops of War are indifferent sailing vessels compared with many in the merchant service. Ships no larger than Sloops of War are built longer than Frigates of the United States Navy, and, as we have shown, ships are now building that are longer than any ship in the Navy, the *Pennsylvania* not excepted. That our Frigates, in their sailing, as well as other qualities, are equal to any on the globe, we have no hesitation in adding the weight of our testimony; but are they not, some of them at least, models of the past century? and are those of the present century superior models to those of the last? does their performances prove them such? While we readily admit that the Navy of the United States, as far as the models of her ships may stand connected with the operations of a Navy, is equal to any on the globe, we do not admit that in this matter we should remain in a state of *eternal childhood*. Inasmuch as American commercial enterprise surpasses that of all other nations, in like manner the American Navy should be the most efficient on the globe. Unless there is a greater improvement in the sailing qualities of the ships of the United

States Navy than there has been, commercial enterprise will not only raise the means for the support of commerce, but it will also build the ships that are to protect it.

With regard to other qualities than those of speed, they lack strength, more particularly if their length be increased; they should be plated diagonally across the frames as steamers are. We have no hesitancy in saying that the shape of the greatest transverse sections are altered from the original mould whenever the ship is under a press of sail with the wind abeam; this is the effect of the weight of her battery, and is often seen in the opening of the water-way seam, where the division of strain takes place at every roll, more particularly when the guns are housed with their muzzles against the side.

The most efficient class of sailing vessels belonging to the Navy of the United States, are those denominated Sloops of War. This class of ships have within a few years undergone an entire change; the dull-sailing, bad-steering, straight and wall-sided, shapeless hulks that disgraced the *National Ensign*, have occasionally been converted into store-ships; others have been broken up, and now few remain as engines of war. Their places have been supplied with others that answer quite

well the object designed; there is yet much room for improvement, but taken as a whole, they are creditable vessels.

The construction of these vessels has been left in the hands of the constructors themselves, who have fully shown the advantages arising from entrusting to mechanics the management of mechanical operations. These vessels, with rare exceptions, are constantly in commission; the exceptions are very generally those periods in which they are undergoing repairs, of which they seem to require much more than ships in the merchant service.

It is not our purpose, nor yet our province, to induct our readers into the path usually followed by writers on Naval Architecture, who have detailed the manner of naval construction practised in the Old world, and the many others suggested by the theorists of an obsolete age. But believing as we do, and for tangible reasons already given, that naval operations throughout the world are very far behind the mercantile marine, we deem it only necessary to point out the most prominent defects in the manner of construction, and show the remedy. We have already furnished the lines and tables of some of the finest and most efficient vessels on the globe, and we have also described the manner of constructing them; hence it only seems to us ne-

cessary to give a general description, inasmuch as many of our merchant ships, in case of a rupture with a foreign power, (possessing a very considerable navy,) could be converted into Frigates, Corvettes, and Sloops of War, in sufficient numbers in the space of three months to render our Navy the most formidable for sailing vessels on the globe; these ships are, as it regards strength, equal to any vessels in the Navy; the enormous cargoes and the press of sail they carry, and the small amount of repairs they require, incontestably prove this. It may be said that were guns placed on their decks, the case would be quite different: we, however, think otherwise; it matters not whether the cargo be guns or railroad iron, and many of these ships carry an amount between decks equal to any battery, besides the great bulk of the same material in the hold. We will go farther and say, that there is no ship in the Navy that is able to do the work that many merchant ships have done, and still retain their shape with the same amount of repairs; the reason will appear obvious, if we but consider that the tanks for water, and the spaces left for kentledge, deprive the ship of a great amount of strength, inasmuch as most of the space occupied by these is filled with heavy bilge strakes, and with sister keelsons; these

render the bottom and bilge very strong ; the top-sides are not overlooked. Very many of our merchant ships have live-oak and locust top-timbers and stanchions ; and as it regards the manner of putting the frames together, are actually stronger than those of the Navy, inasmuch as the distribution of the butts of the timbers is more general. No one in a private yard would think of adhering with any degree of tenacity to the diagonal sirmark for cutting off the head or heel of a timber ; it should be remembered that the greatest amount of strength is obtained from an equal distribution of the butts ; and with regard to the manner of fastening the ships of the two classes, we deem it rather a detriment than otherwise to extend the fastening of the deck frame through the outside plank, and we are not alone in this matter. It is assumed by those whose province it is to determine how much fastening is required, in vessels of war, that the plank should be square fastened to the timbers throughout ; this, it must be admitted is enough, and if enough in one part, why not in all ? Square fastening implies 2 bolts, spikes, or tree-nails in each timber, or 4 in the frame in each plank. It will not be denied that more than a sufficiency is an injury ; in this case it is an injury in two respects : first it weakens the plank, and secondly it causes the timber to rot sooner than it would otherwise do ; and most surely no one will say that the head of the bolt would not rest quite as firm on a live-oak top-timber as on a white oak plank ; and this extension and exposure of the deck fastening through the outside plank, is one of the reasons why the ships of the Navy rot so much sooner than merchant ships, in connection with another, viz., that of a want of proper ventilation. It is notorious, that our ships of war, although built of what is assumed to be the best material, rot in a very few years ; in some instances on particular stations a single cruise of 3 years was sufficient to warrant a new suit of wales. There is much greater pains taken to ventilate merchant ships than ships of war, in addition to the natural advantages arising from the frequent discharge of cargo. We are glad to learn that the Navy department have adopted measures to determine the best or proper time for cutting timber, and the best mode of curing it, or securing it against dry rot ; in connection with this, their investigations also combine a determination of the specific gravity. Those experiments are confined to the three principal kinds of ship timber, viz., live-oak, white oak, and yellow pine, and will be of incalculable benefit to the

naval and mechanical interests of the United States, when we remember that there is no table of specific gravity that is at all reliable for any meridian of North America, and that our mechanics have been making calculations from tables of specific gravity found in European works, we shall begin to approximate a conception of its value; a location in the timbered districts of this wooded country (for practical purposes) will satisfy the most incredulous, that little is known about the productions of the American forest—a location of two years for this purpose, satisfied the author that he knew but little about the natural science of the forest timber growth of the United States. We are doubly gratified to learn that this important and responsible trust has been committed to Mr. James Jarvis, of Virginia, a mechanic whose unbending energy and zeal in the discharge of duty, fully qualifies him for this important trust; and having filled the office of Inspector and Measurer of Timber for the Government at its principal depot for many years, has acquired a knowledge of its defective properties to an extent unsurpassed doubtless by any man in this country. Mr. Jarvis has discretionary power given him by the Department at Washington; he has kindly furnished us with the result of his experi-

ments for the first year, commencing on the 15th of September, 1849, and continuing in regular order up to the 15th of August, 1850. These experiments will perhaps be better illustrated in the following order:—On the 15th of September he received in 12 feet lengths the butts of ten trees of live-oak, and an equal number of white oak and yellow pine. Five of each kind were worked square at the place where cut, and the remaining five were brought round with the bark on; after their arrival they were subdivided into 3 feet lengths. The squared pieces are from 12 to 15 inches square; the round pieces in *bark* from 12 to 15 inches in diameter. The specific gravity of each piece is at once obtained, and then they are located as follows: 4 pieces of the squared live-oak and 4 pieces of the round live-oak *in bark* are placed in tanks under cover, where are the solutions of *corrosive sublimate*, *copperas*, *alum*, and *coal tar*. The same number of white oak and yellow pine pieces, amounting in all to 32 pieces of each species of *ship timber*, one half of which are square pieces, the other half round and in *bark*. These live-oak, white oak, and yellow pine pieces were kept in the tanks submerged one month, at the expiration of which time they were distributed as follows: under cover, in open air,

planted as posts, and laid as rail-road sills. There is a suitable number of the pieces which have not been prepared, also under cover, in open air, planted as posts, and laid as rail-road sills; a proportion of the pieces, one square, and one round, are water-seasoned for six months; after being removed from the water, two pieces are made of one, and one kept under cover, the other in open air. The pieces which have not been in the solutions, are the *test pieces*; amongst these pieces Mr. Jarvis has fitted some together, wood and wood, except having between them tarred paper coated with charcoal dust. A few years will prove by ocular demonstration, which of the solutions, substances, or water, will make timber most durable. The pieces which have had no preparation on them, and are kept under cover, are weighed each month, to observe the amount of the juices or moisture lost by evaporation in one month and in one year. The weighing of the first piece felled in September, 1849, had been weighed twelve times in August, 1850; therefore it will take until September, 1851, before the timber felled and received in August, 1850, can be weighed twelve times. The object in weighing or obtaining the specific gravity each month in the year, is, that he may be able to determine the best

time for cutting ship timber, or whether it is of any material consequence; and by testing the weight of the same kinds of timber in connection with its durability, and thus set this matter at rest. The timber used for these experiments is thus described:—The live-oak and white oak are of excellent quality, and felled purposely for those experiments, with a few exceptions. The yellow pine is not as good as is used in the Navy; its specific gravity will not prove the fact. The very best of yellow pine is not of the greatest density. Pitch-pine is not as good for decks or deck frames as other fine-grained pine from the south. There is a species of yellow pine from about Wilmington, N. C., whose specific gravity is about the same as the pine used in the experiments, and corresponds (difference of time when cut considered) with that found in the table of specific gravities of dry timber—.610. The very best yellow pine timber is that in which the even fineness of the grain is continued to the centre or pith of the tree. By careful observation, much information that is valuable may be obtained from the tables of specific gravity. Notwithstanding the thickness of the bark on the yellow pine and its lightness, (the specific gravity differing not materially from that of cork,) we find that the

pine timber in bark weighs much more than the square timber; this, to the casual observer, would hardly seem possible; the man unacquainted with the nature of yellow pine sap-wood, would be likely to doubt the correctness of the table; but such is the nature of the exterior coating immediately under the bark of yellow pine, that we cannot find a more analogous substance than that of sponge; its retentive properties are very similar, and the turpentine with which this sap-wood is saturated, is the cause of its increased specific gravity above that of the squared timber when covered with bark. The thinner the sap-wood, the less the specific gravity. There is an error in the prevailing opinions in relation to the durability of yellow pine timber. Our Government has become a heavy stockholder in this prevailing error, by acting on the supposition that yellow pine timber required a great amount of seasoning. The consequence has been, that large timber houses have been erected and filled with yellow pine timber, which has been kept for many years, and when in a state of decay has been used both for new vessels and those undergoing repairs; this is a great mistake; an equal number of months would have answered a better purpose than as many years; as it regards the shrinkage of yellow

pine, when in pieces of any considerable size, it shrinks but little when the vessel is in active service, and when used as deck plank, should be made narrow. The convictions of our judgment lead us to this conclusion, that yellow pine requires no seasoning to make it durable; the ebb and flow of turpentine is through the sap, as the specific gravity will show; hence we say, that the capillary tubes of the heart wood have no more of the resinous property (if cut at a proper season) than is required for strength, and to render it durable, which, we think, Mr. Jarvis's experiments will fully prove. The continued use of yellow pine timber in the private ship-yards of this city, have already proved it incontestably; we could name ships, built in this city some 25 years ago, that have their first yellow pine beams in their decks, and we could point to others that have exhibited a durability in their deck frames unknown in the Navy of the United States. Proper care should be taken to clear the timber of all sap; and as it regards shrinkage in the naval vessels, if the same measures were adopted as in the private yards of making strakes of plank narrow, we think there will be no cause of complaint; the strakes of deck plank, clamps and bulwarks of Navy vessels, are too *wide*. There is another error

in that of preparing yellow pine timber in the woods, both for the private and for naval purposes, it being absolutely necessary that the sap should be excluded; the timber should be eight instead of four squared, thus in effect only taking off the sap, (on account of the very best of the timber being next to the sap;) this would enable the builder to work out water-ways and all similar pieces without cutting in as far as the pith on the exposed side of the piece. The present manner of cutting yellow pine timber is a reckless waste; the very best parts of the tree being left in the woods. Inspectors measure square logs clear of sap, and the consequence is, that but a very small three-cornered strip or vein of sap is left on the corners; whereas if at the centre of the length of the log the sap were removed, and the log were measured as in other girth measurements, the most valuable parts would come into the private and public yards; and although it would be somewhat awkward at first to receive timber in this manner, being accustomed to the square log, yet the price per cubic foot would actually be less, and the timber-getter would save in labor what he paid in extra hauling and freight, and not only so, but he would get paid for all the timber he brought. The Government would

save thousands of dollars, besides having better pine timber, were the Navy department to have yellow pine forests at their command rather than timber sheds stored with pine timber, besides retaining the life of the timber by not having the turpentine drawn from the tree before it is worked into timber. As we have already remarked, the most dense timber is not the best, or most durable, because of the amount of turpentine it contains; it is often rendered so near the butt, in consequence of the tree having been tapped while standing, in order to draw off the turpentine. We would prefer the quality of pine we have alluded to in its pristine state without seasoning for durability, provided it were properly ventilated when in the ship. With regard to the density of white oak, it may with strong propriety be assumed that the quality is in the same ratio as the density; but we shall discover that the tables of specific gravity do not furnish an index for determining the best quality, inasmuch as they show the squared white oak timber cut in December and May, to be the heaviest when cut, while at the same time that which was cut in January and July, was of the best or better quality. In order to detect this supposed discrepancy, let us follow the subject farther. The timber in bark will show that our

first conclusions were correct, inasmuch as the timber cut in July is of the greatest density, and that cut in January differs but a trifle from that cut in December; hence we are inevitably brought to the threshold of this conclusion, that no table of specific gravities for white oak timber is reliable for determining the quality, unless its weight can be shown in the bark. The reason of this discrepancy between round and squared timber in its density, is found in the fact that the texture of the grain of some trees is better adapted for receiving the juices than others throughout the entire transverse section, while others receive the supply chiefly through the sap. This latter kind is the best quality; and, as a consequence, is likely to prove the most durable, as well as being the strongest. There may, however, be exceptions even to this, as a general rule. With regard to the specific gravity of the live-oak, as shown by the tables, we clearly discover that the sap-wood is lighter than the heart, inasmuch as the bark being thin, could scarcely reduce the weight as much as shown by the tables. The tables will not warrant this conclusion of white oak, inasmuch as we find that which was cut in March was heavier in bark than when squared. But although the sap

of live-oak and white oak is less durable than the heart, it is generally received with the heart, and as merchantable timber. The lasting property of live-oak consists chiefly in its being entirely void of that acid juice which white oak contains; but this is not all, the whole of the capillary tubes seems to be completely coated and filled with a greasy glutinous substance, that is not found in the sap, which is doubtless the reason why the sap is not rendered equally durable; this substance may be brought out for analyzation by steaming; it takes steam nearly or quite as well as yellow pine. The monthly tables of specific gravity of the *green tree*, furnishing as they do the basis of (doubtless) the most reliable series of experiments ever undertaken in this or any other country, will, we think, be examined with interest by mechanics, and particularly those whose business it is to use the three kinds of timber of which they take cognizance. In addition to the monthly-tables, Mr. Jarvis has furnished us with the mean specific gravity, as made up of the 12 months, and carried the whole out into pounds and ounces *avoirdupois*. We then have a table of the specific gravity of dry timber, showing when and where cut.

THE "GREEN TREE."

SPECIFIC GRAVITY OF TIMBER FRESH FROM THE FOREST—NONE OF WHICH WAS FELLED MORE THAN TEN DAYS BEFORE THE SPECIFIC GRAVITY WAS OBTAINED.

SQUARE LIVE OAK.			SQUARE WHITE OAK			SQUARE YELLOW PINE		
MONTH FIELLED.	SPECIFIC GRAVITY.		MONTH FIELLED	SPECIFIC GRAVITY.		MONTH FIELLED.	SPECIFIC GRAVITY.	
	<i>lbs</i>	<i>oz</i>		<i>lbs</i>	<i>oz</i>		<i>lbs</i>	<i>oz</i>
September 15th.....	1.242	= 77 10	September 15th.....	1.037	= 61 13	September 15th.....	.665	= 41 9
October 15th.....	1.273	= 79 9	October 15th.....	1.069	= 66 13	October 15th.....	.662	= 41 6
November 15th.....	1.274	= 79 10	November 15th.....	1.058	= 61 2	November 15th.....	.658	= 40 13
December 15th.....	1.283	= 80 3	December 15th.....	1.083	= 67 11	December 15th.....	.639	= 39 16
January 15th.....	1.283	= 80 3	January 15th.....	1.068	= 66 12	January 15th.....	.625	= 39 1
February 15th.....	1.252	= 78 4	February 15th.....	1.066	= 66 10	February 15th.....	.673	= 42 1
March 15th.....	1.261	= 78 13	March 15th.....	1.044	= 65 4	March 15th.....	.581	= 36 5
April 15th.....	1.244	= 77 12	April 15th.....	1.071	= 66 15	April 15th.....	.683	= 42 11
May 15th.....	1.258	= 78 10	May 15th.....	1.102	= 68 14	May 15th.....	.583	= 36 7
June 15th.....	1.257	= 78 9	June 15th.....	1.032	= 64 11	June 15th.....	.585	= 37 3
July 15th.....	1.239	= 76 15	July 15th.....	1.123	= 70 3	July 15th.....	.655	= 40 15
August 15th.....	1.245	= 77 13	August 15th.....	1.082	= 67 10	August 15th.....	.639	= 39 16

ROUND LIVE OAK.			ROUND WHITE OAK.			ROUND YELLOW PINE.		
MONTH FIELLED.	SPECIFIC GRAVITY.		MONTH FIELLED	SPECIFIC GRAVITY.		MONTH FIELLED.	SPECIFIC GRAVITY.	
	<i>lbs</i>	<i>oz</i>		<i>lbs</i>	<i>oz</i>		<i>lbs</i>	<i>oz</i>
September 15th.....	1.144	= 71 10	September 15th.....	.950	= 59 6	September 15th.....	.828	= 51 12
October 15th.....	1.173	= 73 5	October 15th.....	.997	= 62 5	October 15th.....	.764	= 47 12
November 15th.....	1.182	= 73 14	November 15th.....	.996	= 62 4	November 15th.....	.777	= 48 9
December 15th.....	1.185	= 74 2	December 15th.....	1.018	= 63 10	December 15th.....	.765	= 47 13
January 15th.....	1.194	= 74 10	January 15th.....	1.015	= 63 7	January 15th.....	.823	= 51 7
February 15th.....	1.173	= 73 5	February 15th.....	1.014	= 63 6	February 15th.....	.780	= 49 5
March 15th.....	1.187	= 74 5	March 15th.....	1.070	= 67 7	March 15th.....	.782	= 48 14
April 15th.....	1.193	= 74 9	April 15th.....	1.013	= 63 5	April 15th.....	.795	= 49 11
May 15th.....	1.182	= 73 14	May 15th.....	1.021	= 63 13	May 15th.....	.744	= 46 8
June 15th.....	1.154	= 72 2	June 15th.....	1.005	= 62 13	June 15th.....	.702	= 49 3
July 15th.....	1.148	= 71 12	July 15th.....	1.089	= 68 1	July 15th.....	.751	= 46 16
August 15th.....	1.176	= 73 8	August 15th.....	1.054	= 65 14	August 15th.....	.772	= 48 4

MEAN SPECIFIC GRAVITY FOR ONE YEAR.

Square pieces of Live Oak.....	(Fractions off.)	1.250 = 76	pounds 11	ounces.
Round " " in bark.....	" "	1.191 = 74	" "	" "
Square " " White Oak.....	" "	1.069 = 66	" "	7 " 16
Round " " " ".....	" "	1.020 = 63	" "	12 " 16
Square " " Yellow Pine.....	" "	.637 = 39	" "	18 " 46
Round " " " ".....	" "	.781 = 48	" "	18 " 46

DRY TIMBER.

KIND OF TIMBER	Kept dry twenty years, and where sold.	Kept dry fifteen years, and where sold.	Kept dry two years, and where sold.	Kept dry and supposed dry enough to put in a ship's deck.	Specific Gravity.
Lane Oak	East Florida				1.065 lbs. cu.
Mahogany	St. Domingo.				979 = 66 12
Locust	Virginia				854 = 61 8
White Oak	Virginia				854 = 61 6
White Oak*		(See Note.)			750 = 47 7
Ash	Virginia				750 = 46 14
Pitch Pine	Virginia				743 = 45 16
Cypress	Virginia				680 = 42 2
Elm	Virginia				603 = 37 11
Cedar			East Florida		571 = 35 11
Common Yellow Pine	Virginia				520 = 33 8
Poplar	Virginia				516 = 33 8
White Pine	Susquehanna				418 = 26 2
Long Leaf Yellow Pine				near Wilmington, N. C.*	418 = 26 2
Baywood Mahogany	Campeachy.				410 = 26 2
					518 = 32 6

NOTE.—This is a part of the keel of the old Macedonian, taken out when she was broken up. We do not think it was English oak, it being very rare. It was most probably cut in British America, inasmuch as English oak is of as much density as ours.

We have shown by the hydrostatic balance, Fig. 4, in chapter 1, one method by which the specific gravity of any body, whether a floating body or one more dense, may be determined. The term specific denotes that its gravity or weight is determined by comparison with water, inasmuch as distilled water is recognized to be universally the same when pressed under the same weight of air. The expositions given on page 28 of the manner of using the hydrostatic balance, will doubtless be sufficient, and render it unnecessary to extend our remarks upon its use and advantages. Another remark in relation to the durability of timber, (white oak in particular,) when in a green state, and the causes of its decay, may suffice. It is doubtless true beyond a doubt, that in many instances more than one-half of the actual gravity of timber is made up of the juices; hence it is plain that the seasoning process is but a removal of this moisture by evaporation; the inquiry then follows, which is the best mode of evaporating this moisture, by slow or sudden means? and should we be deprived of the use of the timber while this operation is being performed? We think the day is not far distant, when it will be proved by ocular demonstration that timber can be seasoned in the vessel, without storage

for that purpose, by a proper mode of ventilation. Experience has shown that vessels employed in hot climates (unless the timber be well-seasoned) rot in a very short time; but let this same vessel be employed in a climate colder than that in which she was built, (or the timber was cut,) and she will continue sound for years; from this we may learn, that vessels built of green timber, or that partially seasoned, should not be sent on stations where the order of seasoning is reversed, and a fermentation of the acid takes place, which will rot any timber vessel within a very few years. Enough might be said upon this subject to fill a volume, and we hope that the untiring zeal of Mr. Jarvis, in his philosophical investigations, will elicit such information as shall fill up the great chasm in mechanical knowledge, so necessary in the construction of this stupendous fabric, and upon a subject of which the mechanical world is avowedly ignorant, and we are quite well assured in our own minds that a volume upon this subject would meet with public favor.

But to return to the subject of ventilation—we say that there is abundant room for improvement in the Navy of the United States in this particular. In the Sloops of War, as in other vessels of the Navy, an air strake

is formed, or an open space of 3 or 4 inches left between the clamps and sperketting between decks; this seems rather as a conductor of foul, than of fresh air; we should rather be inclined to the belief, that were those openings closed, and the ceiling made tight by calking, as also all communication with the timbering room below the upper deck, there would be less cause of complaint. The only communication that should be had with the timbering room should be above deck, where access to the pure open air can be obtained. This mode of ventilation is fully accomplished in merchant ships, and at the same time water or any other substance than air is not admitted; it is true that between the knees and the deck plank the air may have access, but the channel is very small, and the excess of draught above would neutralize its effect; a vessel is properly ventilated when at the limber strake an apparatus is arranged that shall be to the ship what the fire-place is to the house, while another on the plank-sheer, port sill, or rail, shall assist in drawing out the foul air, as the smoke is drawn upward, the timbering room representing the chimney; this may be placed on one side of the keelson, while on the opposite side of the keelson the same kind of instrument that is found on the rail of the first side, and the fire-place draught on the rail; this reciprocal change alternately, it will be perceived, would draw out the foul air on one side and supply the fresh air from the opposite side, changing alternately. It will be perceived, that the only thing required to accomplish this is the apparatus for the generation of a current from below, and the removal of obstructions from the passage above, at the same time preventing the water from entering through the same channel; this has recently been partially accomplished in some of the merchant ships of this city. Free access may be had with the open air through an orifice in the plank-sheer, and yet the water cannot enter, inasmuch as the orifice is closed when the bent tube is submerged; this is done by a ball simply floating into the orifice, which effectually closes it against water, and when the water subsides, the ball drops down, when air is admitted; this contrivance, though simple and useful, and doubtless equal if not superior to any other, lacks another to be placed at the lowest part of the timber room for the purpose, as we have said, of generating a draught, which will effectually draw off the foul air, which causes vessels to rot so much faster in the naval than in the merchant service, and would prove much more effectual than filling the timber-

ing room with salt, which has prevailed to a very considerable extent. The Sloops of War of the Navy should have a light spar deck, and there are several reasons why; first, the ship would afford greater facilities for ventilation, and if advantage were taken of those facilities, the ship would be more durable; another reason may be shown in the improved health of the crew. It cannot be denied that pure air, or a more extensive circulation than can be obtained below the gun-deck of a Sloop of War, would contribute to the health and comfort of the crew. On the coast of Africa, or even on the West India station, the addition would be of incalculable value, inasmuch as a free circulation of air through the ports might be obtained, and benefit the entire crew, who could suspend their hammocks to the spar deck. This additional deck would not increase the battery, nor yet the number of men, and surely every Sloop of War should have a sufficiency of stability to carry a light spar deck. This class of naval vessels are rendered doubly serviceable, in consequence of their draught of water, which is sufficiently light to enable them to have ingress and egress at all the ports of entry of any considerable size; and next to the War Steamer, the ship commonly called the Sloop of War, (more properly denominated the

Corvette,) stands at the head of the list for usefulness. In this age of fire, water, and vapor power, it must be admitted that the War Steamer is most reliable as an engine of war or a messenger of peace. It must not, however, be supposed that power for weal or wo in a War Steamer consists in the number of guns mounted in dread array. In the steamer, as in other vessels of war, a small number of large calibre located in selected positions, will accomplish wonders. But the main object in their construction is not to make mere floating batteries; this kind of vessel belonged to an obsolete age; a War Steamer is formidable in proportion to her speed and the weight of her shot; a single swivel gun, carrying a 10 or 12 inch shot, is more formidable than a broadside of 42 pounders; and a War Steamer, carrying 12 eight or nine inch guns, and 2 twelve inch pivot guns, would be of much greater service than the *Pennsylvania* with her three gun-decks and spar deck, provided she could use them all.

With regard to the relative excellence of the models of naval and commercial steamers, the latter very far surpasses the former in the United States. As we had occasion to remark in relation to commercial steamers, that to be profitable, they must be

fast; so we say of War Steamers, to be serviceable, they should be fast. He who is behind in this age of the world, is *ever chasing lost time*, a part which the American character repudiates. We would not be misunderstood in this matter; we do not say that commercial steamers are better vessels, but that they are better models for this great desideratum, viz., *speed*, and, consequently, are preferable for War Steamers. Instead of being behind, they should be even faster than those of the merchant service. It is evident that the two kinds of vessels require the same models, inasmuch as they both aim at the same important points, viz., stability, speed, and easy draught of water. A steamer for commercial purposes must be able to go in and out at the ports for which she is destined; and a War Steamer should be able to enter almost any port where fuel may be obtained. All commercial steamers of any considerable size should be so constructed that they may at any time be converted into War Steamers; this could be accomplished, and the Government at all times would have a respectable force in steamers, that would be in advance of other nations; this could be accomplished without material additional cost of construction; it would only be necessary for the Government to know the quality

of the vessels built, in the same manner that the underwriters do, and this to the Government would be but furnishing employment for those already under pay, thus (we have assumed that naval officers would be selected for this mechanical operation, as has always been the case) not only millions of dollars might be saved to the Government, but the mortifying reflection that her steamers were behind the age, notwithstanding they had cost more than enough to place them in advance—they were comparatively slow, though they had cost enough to render them efficient. The continuation of the former practice of modelling vessels of war, as well as other vessels, for generations yet *unborn* to build, is entirely wrong, as whole frames of steamers and other vessels bear witness; these frames were cut to the moulds, and bevels made by models the Government have repudiated, and the timber is condemned because of its having been shaped out by an inferior model; we say the promiscuous timber used in the private yard is far better adapted to working the ship's frame, than that which is worked out; any mechanic can mould out a better frame where he has the variety of crooks before him on the ground, than when selecting the shape from the tree while standing. The strength of Ocean

{ main a proper
conclusion.

Steamers, whether for commercial or war purposes, should be unquestionable; and the one requires quite as much as the other; and all the means we have named for adding strength to the commercial is equally applicable to the War Steamer. Few steamers that are very fast carry much freight, but doubtless quite enough to be equal to an amount of armament sufficient both in calibre and extent for a War Steamer, in addition to her provision and fuel. The weight of War Steamers differs but little, from $\frac{1}{2}$ to $\frac{1}{3}$ of their load-line displacement; much of this, however, depends upon their principal dimensions, as well as their shape; no proportion of the registered tonnage can by any possibility apply to the weight that may be considered a reliable rule, inasmuch as any alteration in the dimensions would increase or diminish the weight; for example, we may add to the depth 5 feet, and take off the breadth but one inch, and the tonnage is less, although the ship would weigh perhaps 10 per cent. more. The carpenter's measurement, or any other than that of the displacement, is not a reliable standard. The remarks found on page 345 in relation to the shape of the bow of an ocean steam-ship will be found equally applicable to those intended for war purposes. It requires but a mechanical glance to discover

that the line of flotation of every steamer in the Navies of the Old or New World are fullest at the stem, and, as a consequence, the bulk of the wave generated by the bow is found at the wood ends, or along the bow close by the stem; this must of necessity be the case on every bow that has a longitudinally round line of flotation, and in Chapter 10 we contrasted the motions of the narrow, straight-sided and round bow of the steamer at sea, to her suspension in the turning lathe; so with regard to the longitudinal motion on the bow that has this fullness at the extremity. The man who doubts the tangibility of the demonstration we have given, needs but to apply the protractor to the bow of any vessel having a line of flotation continued round to its extremity, and he will at once discover that, as we have said, the fullest part of the bow is at its extremity; and if fullness and resistance mean any thing, he must admit, (however unwilling,) that the greatest part of the resistance on the bow is at the wood ends; that is to say, the same area at that part has more resistance than an equal amount of surface any where else, or at any other part; we have been thus particular in defining our position, inasmuch as we are but too well convinced that it conflicts with the hereditary notions of the age, and

that it will meet with more opposition on both shores of the Atlantic Ocean than almost any other that might be demonstrated with an equal amount of tangibility; but the candid man will look at the position taken in all its bearings, and if his perceptive powers are not remarkably obtuse, we have no fears of the result.

In defining the proper shape for war vessels, we are well aware that we are navigating a dangerous coast; the dogmatical supremacy assumed by this branch of the Government, would lead the casual observer to believe that here was the consummation of the perfective qualities to be found, and no where else; but a careful and close observation has taught commercial men that this (once the right) arm of national power is diseased, and that unless a cure is speedily effected, amputation must inevitably be rendered necessary. England has learned this *truth*, that her Navy (itself considered) could not keep pace with her maritime interests; hence she found it necessary to foster such a direction of individual enterprise as could be made available for national purposes; how far a similar course may be made available for the better security of national honor on the part of the United States, it is not our purpose to examine, or our province to discuss.

We say this, that a few War Steamers, capable of carrying a battery as has been designated in this Chapter, and provision and water for one month, and capable of being driven 15 miles per hour, (which should be considered a moderate speed for a War Steamer,) would be more formidable and efficient than all the registered Navy of the United States. This desirable quality can only be accomplished by large vessels—a steam-ship even of 2000 tons is a small affair for naval purposes; if she has any considerable amount of power, she is entirely full with nothing but her engines and coal, and even for a light draught of water, (not exceeding ten feet,) a steamer cannot be built (that shall be adapted to all the purposes of war) of a smaller tonnage than 2500. War steamers need not draw a heavy draught because they are large—16 feet is a sufficient draught for a steamer of 3000 tons. A vessel as already described, drawing but 10 feet water, would require a great breadth, with reduced depth, and an easy bilge, to prevent her rolling; her depth should be even less than half of the breadth, and she would require additional strength on the sides, and at every available part; for example, the coal bunkers, that have been merely regarded as bulk-heads to confine the coal within certain limits, may be made

to add very materially to the strength of the ship, extending through each transverse bulk-head.

We have shown at different parts of the work the proper measures for increasing the strength of vessels; and Ocean Steam-ships, whether for commercial or for war purposes, require all the strength that can be made available with the ordinary means.

Our Government determined to build a War Steamer some years since for harbor defence, and after having purchased iron for the purpose, the project was abandoned, at least for the present.

Experiments in England have proved the futility of attempting to render the sides of iron vessels impenetrable by shot. We are persuaded, however, that the most formidable description of vessel for harbor defence would be such as carried no guns, presenting an angle that would be impenetrable by shot; such vessel, built of iron, and driven at a speed of 25 miles per hour, would go into the broad-side of any vessel quite as far as would be necessary to sink her in a few minutes, without the firing of a single gun; this vessel might be so completely housed and made shot-proof that its crew would be securely protected, being so sharp that neither the hull nor its cover could be affected by shot. The power of such

a vessel to strike a blow, the effects of which we have described, may be judged from the effects of a collision of one of the comparatively frail steam-boats on the Hudson river: an ordinarily sharp boat will cut a sound sailing vessel in two, and at the same time the shock will scarcely be felt in the ladies' saloon, or at the captain's office, while the boat herself is not materially injured. Collisions of this kind have fully proved that the sharper the vessel, the more of longitudinal strength she possesses; and if we but contemplate a vessel built for strength and speed, we may readily conceive of its power to strike a blow that no vessel could resist—it would be equal to that of a train of rail-road cars of equal weight running into an embankment at the speed already named. Guns for harbor defence should be on *terra firma*; they are little better than a useless appendage, for the protection of the harbors or bays of our extensive coast.

With regard to the application of power for propelling War Steamers, the side paddle wheel is objectionable, on account of its exposure to shot, and the inequality of the dip on the two sides; the smallest roll effects a material change in the dip of the bucket, even if the vessel should not roll, but remain perfectly stable, this

change would take place, and cause a loss of power; with the side wheel a larger amount of dip is necessary, in order to secure a continued unvarying resistance from the wheel. The propeller in some respects might be considered preferable for War Steamers, but the seeming advantage arising from its security against shot by its peculiar location, is counteracted by the difficulty in making repairs; the vessel must be docked when the smallest amount of repairs are required. As it regards the effective qualities of those two modes of applying the power for propelling steam-ships, we are persuaded the side wheel is preferable, inasmuch as the gearing necessary to obtain the required speed of the propeller, adds to the risk, and renders this mode of application more liable to derangement than a more direct application, which the side paddle wheel is recognized to be; this, in connection with the ready manner in which the side wheel can be repaired, renders it preferable. We are persuaded, however, that there is a wide field for improvement in the propulsion of steam-ships. In relation to the security of the machinery against shot, the coal bunker when full would furnish some protection.

The question has been, and is now agitated, resolving itself into a problem,

the features of which appear to be like the following: provided the propeller can be unshipped, or by a coupling joint be lifted out of water, to enable the sails to be used to advantage, would it not be preferable to the side wheel? The same may be said of the side wheel: the buckets or paddles may be taken off; not, however, without difficulty when at sea.

With regard to the propriety of sparring War Steamers with the same weight of spars that a sailing ship of the same size would carry, we say the practice is manifestly wrong. They are only required as jurmasts, to be used when any derangement of the machinery takes place. Steam and sail work very well together when the wind is fair, but the steam-ship that cannot be worked in an open sea without sail, is a poor affair, either in model or power; a vessel whose principal advantage consists in being able to help sailing vessels when unable to help themselves, herself depending upon sail for the faithful performance of her duty, renders her at once unworthy of the name she bears; apart from another consideration, that they have enough to carry without this unnecessary appendage, an equal weight in coal would be of much more service. War Steamers furnish abundant room for improvement in almost every part.

Having shown in our remarks on river steamboats the manner of computing horse power, and what are the disadvantages of the ordinary side paddle-wheel for Ocean Steam-ships, we should prove recreant to our purpose did we not show what has been done by way of improvement in the application of power on War Steamers as well as Coasting Steamers in Europe, and contrast those improvements with what has been done, and is now doing, in the United States. In England an improvement has been introduced—the wheel of Wm. Morgan has been successfully applied, not only to steamers running coast-wise, but the War Steamer *Medea*, of about 800 tons, and 220 horse power, has been made the subject of this experimental wheel, and has shown its superiority over the ordinary wheel. The Morgan wheel has the advantages of entering and leaving the water vertically—a quality not possessed by the side paddle wheel. Its reputation in England has been, and is still, such as to render it worthy of a more extended notice than our pages will justify—its description may be seen in the works of Tredgold.

While England has been improving, Americans have not been idle. The wheel of Mr. Abner Chapman, of this city, is worthy of notice. This wheel, after having had several successful

trials, has been placed on the steamboat *Santa Claus*.—Length 208 feet; breadth 25 feet; draft of water 5 feet; cylinder 48 in diameter; 10 feet stroke; diameter of wheel 25 feet; 7 feet face; 24 revolutions per minute. The velocity of this boat was $\frac{\text{feet}}{1491}$ per minute, or $\frac{\text{feet}}{24.85}$ per second; relative velocity at periphery of wheel $\frac{\text{feet}}{8.55}$ per second, or $\frac{\text{miles}}{4.46}$ per hour; relative velocity at centre of pressure $\frac{\text{feet}}{4.66}$ per second, or $\frac{\text{miles}}{3.17}$ per hour. The gain on Chapman's patent wheel equals 15 per cent. of former speed of boat; calling the slip of the flat bucket unit or 1, the slip of Chapman's bucket equals .57 at the centre of pressure of the wheel. The buckets of this wheel are made of plate iron in two parts, and of a curved form, running from the side arms to the next centre arm back, with an opening between them at the centre arm of half an inch to each foot of diameter of wheel; the ratio of gain of this wheel is about equal at all immersions, which is not the case with the Morgan wheel.

On Chapman's wheel all parts are fixed permanently, while on the Morgan wheel the buckets are worked by an eccentric arm; and by the number of moveable parts, it must of necessity be both expensive in its construction and repairs.

CHAPTER XII.

Laws of Beauty and Taste—Hulls and Sterns—Compend of all the Rules for Masting and Sparring Vessels of all description—the Author's Improvements.

The French rhetoricians have a maxim that there is nothing beautiful that is not true—an axiom that applies to ships as well as other things. From time immemorial first impressions have been well nigh omnipotent, and men have in all ages set a value upon those impressions above all price, and in by far the greatest number of instances, the impressions made at first sight have followed their possessor to the threshold of the grave. The Chinaman is doubtless quite as tenacious about the size of the eye he paints on the bow of his Junk as the ship-builder of modern times would be about the size of the hawse-hole, and in both cases the constructor would be governed as he supposed by the principle of utility. How important then that the principles of utility should form the mechanical alphabet for the inexperienced, and not the opinions of others! There is a certain fitness that is characteristic of every art, and although there are few indeed who can follow in their mind's eye all the various parts of this stupendous fabric in detail, yet to us the reason appears obvious: they have never allowed themselves to think independently of the opinions of others; this practice has been continued until they cannot think for themselves, and, as a consequence, they are fettered by the opinions of others. We hold that no man can improve to any considerable extent either in ship-building or any other branch of mechanism, whose volitions are not the result of his own conceptions.

With regard to beauty in ships, we have said that it consisted in fitness for the purpose and proportion to effect the object designed. The eye of many men remain uncultivated for a whole life-time, in consequence of their not having studied the analogy of proportions, found only in nature; the consequences have proved fatal to the philosophy of mechanism; let the branch be what it may, proportion is the universal *alcahest*, and dissolves before

the cultivated eye the mightiest fabric into one of smaller magnitude—this is as equally true of the pyramid as of the ship; it is seen in nature from the mighty oak, (the monarch of the wood,) whose giant arms have dared the blasts of an hundred winters, down to the smallest shrub; all Nature teaches us that her works appear to the eye smaller than they really are.

We were led to these reflections from a knowledge of this fact, viz., that a great many ships are built whose appearance is really disagreeable to men of taste on account of the clumsy appearance they present, consequent upon the heavy appearance of the head or stern, or some other part that may be disproportioned. It is not the many mouldings on a ship, or the amount of carved work on the head and stern, that makes her appear to have life; so far from adding to the appearance of a handsome ship, they detract from it, and it is only the disproportioned ship that requires those external superfluities to make her passable; indeed, we have often seen a ship that exhibited a much handsomer stern with nothing on it, than another with a full taffarel. These remarks apply with equal propriety to the head; the setting of a head on the bow of a ship has been considered to be one of the most difficult parts of

construction, inasmuch as the eye must determine its every part, and we sometimes see ships that fully exemplify this. There is a certain effect consequent principally, but not entirely, upon the sheer and the rake of the stem: those lines, if proper attention is paid to their direction, will furnish a point to which every part should tend. If the bow be longitudinally sharp, or have a very considerable rake, the cut-water should extend farther out than though it were less sharp, or had less rake. This leads us to another conclusion, viz., that the chances for securing a long head are less on the sharp than on the full vessel; hence it will appear quite manifest that a just medium should be observed, and if the ship should appear to require a long head, it should be reduced vertically.

We completed our expositions on the general outline of the construction of a ship (with the exception of the head and stern) on page 315; we shall now follow up the connection, and finish the ship.

On Plate 4 we have illustrated the manner of laying down the stern on the floor; the detailed description of the manner in which this part of the operation is performed may be found on page 138. When the stern is thus laid down on the floor, the side counter timbers are worked out in the same

manner as any other timber of the frame; they are also raised and secured to the ribband at the rail height; there should be a harpen made at the height of the rail, the top of which should range with the sheer; this would be all the ribband that would be required; the timbers being worked out by the counter timber moulds, would find their proper location on the transom; it being assumed that the distribution of the counter timbers has been so arranged that the cabin windows will come between the timbers, and taper as we advance toward the outside from the centre, as in Fig. 1 of Plate 26.

The practice which now prevails almost universally of building sterns, is as follows: the side counter timber is made to conform in its rake with a mould that is temporarily nailed to the side of the stern post; two half timbers are also worked out, extending no higher than the arch-board is designed to go; along side of these half timbers on each side of the post, a counter timber extends to the rail, and is fastened to the post; the reason for keeping the counter timbers off from the post by half timbers is, that the rudder-stock, which is larger than the post, may not cut the whole timbers; a second reason is, that the windows could not be properly divided with the centre tim-

bers so close together. When the centre and the corner timbers are in their place, a ribband is extended across the stern at the heads, or a short distance below, and the arch-board is then extended across the stern; it will be discovered that, as we have shown in Plate 4, the arch-board rakes at a different angle from that of either the stern or the counter; that it is adjusted between the two angles; the stern timbers above the arch-board being straight, no other ribband is rendered necessary. It is customary to give the arch-board about the same vertical round as the beam mould; this would require much more on the board itself, inasmuch as its rake and round combined, demands much more sni or crook edgewise, in order to obtain the round of the beam mould above a horizontally straight line. We have shown in Fig. 1, Plate 8, the manner of obtaining a true sweep for the arch-board, after we have determined how much sweep we require; the board is usually of oak, and the same in thickness as the plank on the counter and stern; its width for the smallest ship, as we have said, is seldom less than 12 inches at the centre, and somewhat less at the side of the stern; the ends are usually extended quite across the wale, and are shown on the outside, until covered with the quarter piece; below the





arch-board the ends of the wales are partially cut with a mitre for several strakes down, when the mitre becomes more complete, and extends quite across the transom to the post; thus it will be perceived that some of the ends of the wales are seen below the arch-board, as we have said, for several strakes. We do not think this mode a good one, for the following reasons: in calking the cross seam in its continuation from the post to the arch-board, that part where the mitre is incomplete has a tendency to start the wales off, inasmuch as the seam makes the ends of the counter plank much nearer square than those of the wales. We have mitred the entire seam below the arch-board, and deem it preferable to the present mode; above the arch-board all the plank extend quite across the stern; it has been the custom to plank the stern above the upper arch (which forms the vertical size of the cabin windows) promiscuously, or without reference to the direction of the seams, and then lining the stern above and below the taffarel; but this practice is objectionable, inasmuch as it causes the stern to rot sooner than other parts, besides it does not look so well; the stern should be planked with narrow strakes, not certainly wider than the deck plank, and properly diminished from the taffrail down each

seam, showing the round of the taffrail, and differing gradually to that of the arch-board; by planking the stern with narrow strakes, we may be able to do so with straight plank; they may, and doubtless will require to be steamed. With regard to the shape of the taffarel, little can be said that would be applicable to all descriptions of vessels further than this: the taffarel, or whatever finish decorates a vessel, or is intended to do so, should be made to correspond with the vessel. The idea of having one taffarel mould, or one cut-water mould for all vessels, no matter what the form may be, is without a foundation in the philosophy of Nature's laws. If the ships are alike in form and finish, it is then not out of place; but if the models differ, all other parts should be made to correspond. Some builders have labored to make it appear as a want of decision of character in the man who would not build two ships alike, but would adapt his model to the trade of the ship, even though the dimensions were the same, or nearly the same; to us, however, the continued sameness which stamps all vessels built by the same man, is a manifest weakness, and admonishes us that the man has but one *idea*; in other words, that he can only *wade*, or he would venture into deeper water, and be governed, to some extent at

least, by circumstances. If, for example, a ship be longer than another of the same model, the only difference being in the expansion of the model, does it not follow that the head and stern should also be expanded? We are persuaded that no mechanic would decide against us; and yet we see ship after ship, no matter what the size, with the same sized head on; it is not enough to rake, raise or lower a cut-water mould, and say that all is right! The laws of proportion apply as fully and as fairly to heads and sterns as to any part of the ship, and that which was designed to ornament a ship is sometimes made to disparage her beauty; neither is it enough to say that one builder's heads and sterns are equal or superior to another, or to any. We say, and without fear of successful contradiction, that every ship's head should be adapted to the ship. If a ship seems to require a long head, she requires an adaptation aft in the rake of the stern; or if we have no head, we require less rake to the stern; another feature with regard to the sterns of ships: they are made to appear heavy by their continued sameness or equality of rake; a twist to the stern imparts a life-like appearance, and while the corner of the stern may, for appearance, have all the rake necessary, the centre may have less, and will furnish a stronger stern. The altitude of the arch-board is usually determined by the size of the rudder, inasmuch as the counter is extended above the stock of the rudder at least one of the strakes of the same; and farther, the cabin windows are designed to furnish light below the main deck beams, which must of necessity keep them down. The practice prevails of having alternately every second window, such only in appearance, it being a false window; this is accomplished by rabbeting the timbers sufficiently deep to receive plank of the same thickness as the stern, and sunk back flush with the moulding edge of the timber; this blank surface is made before the upper arch-strake is put on, which covers enough of the upper part of this false light to make it tight with light calking; the same may be said with reference to the arch-board, the plank forming the false light extends below the upper edge of the arch-board in the same manner as above; the vertical edges that rabbet into the timber are covered with the pilaster which covers the timber; cabin windows on the stern are usually made wider than their depth on the face of the stern, inasmuch as the stern is broader than deep, and not only so, but any extension above the usual depth would be useless, being directly in range of the first beam next

to the stern. The beauty of this part of the stern consists in having more round to the stern at the arch-board than elsewhere; also to have the upper and lower arch taper as we recede from the centre; in addition to this, the width of the windows should taper in width, and the pilaster should also be reduced as we approach the outside of the stern.

Where those little things are attended to, the casual observer is at once struck with the symmetry that is exhibited, and is pleased with the appearance, but cannot tell why; there is a certain something that makes an impression on his mind; in other words, he has seen proportion somewhere, and if nowhere else, he has seen it in the looking-glass when recognizing his own person; and now he sees the same trait, viz., proportion reflected back, and he at once recognizes it. It would be the same with any other piece of mechanism, a house, a church, or even a barn; and if the casual observer can appreciate proportions, how they must loom up to the man with a cultivated eye, who has taken Nature for his model, and has adhered to that model with unfaltering fidelity!

As we have before remarked, we can give no stereotyped dimensions that will apply to any vessel; we may and shall give an outline that has, or

does look well on a certain ship, but it does not follow that the same will apply to any other ship; and although many have deemed it the part of weakness to be changing, we deem it quite the reverse; no one would suppose that it was an exhibition of folly to require the tailor to make a coat fit in every part; and although the reader may weigh precisely the same, and be exactly of the same height as his friend, yet he would rather the tailor should measure himself than his friend for the coat he was about to make for him, and why? simply because he thinks it will fit better; so we say of ships with this qualification.

We will now do what we promised. The arch-board for a ship of 1000 tons may be about 13 inches at the centre, and 11 to 11½ at the ends; the upper arch may be about 18 inches above the lower one at the centre, and 16½ to 17 at the outer window; if we prefer a window in the centre, it must be a false one, on account of the rudder, and may be 2 feet wide, both above and below, joined by a pilaster on each side; these pilasters may be 1 foot wide and parallel; the next window on each side may be 21½ below, and 21½ above, followed by pilasters 11½ below, and 11½ above; the next two windows, one on each side, may be 21½ below, and 20½ inches above, followed by two

pilasters $11\frac{1}{2}$ below, and $11\frac{1}{2}$ above; we now have 5 windows; the next two may be $20\frac{1}{2}$ inches below, and $19\frac{1}{2}$ above; thus it will be seen that we make the taper greater as we approach the outer window. With regard to the number of windows, the width and shape of the stern will determine this; neither can the tafferel be delineated; it may land on the arch-board, as it has almost from time immemorial, or may be conducted around the quarter, and under the arch-board, any way in which it will best fit the stern. We have shown two modes, the one on Plate 9, where there is no counter, and the wood ends run up to the lower edge of the arch-board, and lights are inserted instead of windows, which are preferable; these lights are weather-proof, and are more secure; they are hung with hinges, and closed with a hand screw to exclude the weather. The second, Plate 10, shows an easy quarter, with lights instead of windows, and the tafferel turned under with counter, but no arch-board; a single moulding continues the upper wale across the stern. A mechanic will at once discover that the old stereotyped tafferel would not and could not be made to appear well on a stern in the form of Plate 10; and who will take the responsibility of asserting that this, or that of Plate 9, are not better cal-

culated for every necessary sea quality than the old-fashioned stern?

There was a time when a merchant ship must have quarter galleries, to give a majestic, warlike appearance, inasmuch as this, with every thing else copied from the Navy, must be right: few dared to call in question the propriety of the addition; and to the present time some English merchant ships have quarter galleries.

The day has gone by when the Navy will be taken for a pattern in any branch of commercial operations. Individual enterprise must furnish a basis for naval operations in ship-building, unless its improvements are in future more rapid than they have been. We want the quarter reduced to its lowest possible dimension or size, for the benefit of the ship, in order to equalize the lines of flotation.

With this general description of sterns, and the manner of building them, we leave this end of the ship, and go forward on the head: this, like the stern, should be adapted to the form of the ship; the whole bow and rake of the stern should determine its size and form. The head may be laid down with the ship, as we have shown, but the practice is quite common of making a mould on the ship about the time the ship has her decks framed, ceiling in, and wales on; this is the

most suitable time, inasmuch as the head cannot be finished much before the ship is ready to launch; and yet there is time enough to finish the head if it should not be commenced until the vessel is planked; there is this objection to delay: the carver must or should have all the time that can well be allowed, (unless they have time on their hands;) the head cannot be set until the hawse-holes can be located. A surface of boards is extended beyond the stem to the extent we design the cut-water shall be; upon this crude mould battens are tacked to represent the front of the cut-water and the cheeks, and when they conform to the eye, they are marked, and the mould taken down, not however, before it is fully determined whether the head rail shall blend into the plank-sheer moulding, or continue in that direction for a suitable distance, and then suddenly turn and conform to the size and direction of the cat-head; this is a matter of taste with the builder. There appears in our minds to be but one objection to the head rail uniting with the cat-head, which is its consequent increased size at the after end, which imparts a heavy appearance to the whole bow; the head rail starting from the same point, viz., the figure head, should not be larger than the cheeks at the starting point, which they must of necessity be when it is designed to end at the cat-head; much, however, of this heavy appearance may be removed by the taper of the checks and head rail. Suppose the head rail to be moulded four inches at the figure, and twelve at the cat-head, it follows that the usual taper would be eight inches at the centre; this would impart the heavy appearance of which we complain; six and three-quarters to seven inches is all that is required; and if the strength is deemed insufficient, it may be increased beyond the regular taper in the siding direction. With regard to the cheeks, they should swell beyond the regular taper, inasmuch as their size is not commensurate with their length; their strength is secured in the transverse direction, for we discover that at the figure they are but $1\frac{1}{2}$ inches; while at the wood ends, if the line were continued across the throat of the knee, they would be 12 inches or more; again in the siding direction they may be $2\frac{1}{2}$ inches at the figure, and $6\frac{1}{2}$ to 7 inches on the bow; what we mean in the taper of the cheeks is, that half way between the figure and the bow, the cheek should be moulded, or show in the vertical direction more than half of the difference between the two terminations; that is to say, if the bracket or following piece of the cheek were $2\frac{1}{2}$ inches at the

figure, and $6\frac{1}{2}$ at the bow, it should be at least $4\frac{1}{2}$ inches to $4\frac{1}{2}$ at the middle of length, instead of $4\frac{1}{2}$, which would be the regular taper; by thus relieving the one of the extra heavy appearance, and the other of its consequent (when contrasted) light appearance, we approximate that symmetry so essential in the appearance of a vessel's head; one quarter of an inch seems to cover but a small space in the eye when looking at a ship's head, but even that may be seen readily, and may be added to or taken from the cheeks or head rail, and be noticeable at the first glance of the practised eye; the difficulty with many mechanics lies just here: they cannot determine when the form is right, or detect error in adaptation of the one to the other; they have become so accustomed to let others do their thinking, that they find it difficult to think for themselves.

There is a certain fitness about the head of a ship that at once stamps an impression on the mind in relation to the entire ship, and why? We say that the head of a ship is like a portrait, we look at the physiognomy of the man, and judge of his intellectual endowments—of his internal and his external qualities; so with the ship, it is the builder's mechanical portrait; and curiosity or quest of knowledge has often attracted men on board of

certain ships merely on account of the peculiar symmetry of the head or stern.

It is designed as an ornament to decorate the representative of a thing of life, and any thing that would in the least mar its beauteous proportions, should be studiously avoided.

It was formerly the custom to keep both of the cheek knees below the hawse-holes, but of late years the practice has grown obsolete, and the hawse-holes come between the cheeks, and the improved appearance is quite manifest.

It may not be out of place to show the only correct way to side cheek knees, although it may be thought by some that this operation is so generally understood, that it would be entirely superfluous; we, however, think quite differently. There are very few, even among those who do little else besides set heads and sterns, who can side a cheek knee properly, and we have seen heads greatly depreciated in their appearance, in consequence of a discrepancy in this particular. It must be quite apparent, that whatever of the knees extends beyond the wood ends towards the stern, should be of the same size as that at the wood ends; and that on the sharp vessel, if the after end of the knee or the end of the body extends farther aft than the corner at the wood ends, it should be sided by the upper



1. The first step is to identify the main components of the system. This includes the hardware (CPU, memory, storage) and software (operating system, applications).

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1. The first step in the process of identifying a problem is to recognize that a problem exists. This is often done by comparing current performance with a desired state or goal. If there is a significant difference, a problem is identified.



edge of the mould, because the lower side is continued parallel on the bow; most persons continue the mould no farther than the corner, when they mould the arm, or the part that comes against the cut-water, and then obtain a spot through the throat, winding out the rest of the face by this spot. This is manifestly wrong, as will appear upon a moment's reflection. Who can tell at what angle this spot must be obtained in the throat? If the cheek knee be out square, which it undoubtedly would, let the mould extend beyond the corner at the wood ends, and as much farther as will bring the end of the mould and the end of the body of the knee on the bow in a line square from the arm against the cut-water; this of course comprehends a square knee, and then the secret is all out; let the spots be put on parallel to this line, or put a spot on the knee that shall be parallel to this line, and at the same time having one edge of the straight edge on the mould when the spot is obtained; this is what we require of the mould for siding the knee; after having marked by its edges on the arm the size of the same, it will readily be perceived that the remaining spots may be pricked off, being parallel and out of wind with the first, and thus the knee may be counter-moulded, and will look fair from more than one posi-

tion; it will appear fair from any view we may take. The space between the cheeks will also have a proportionate taper, likewise the opening between the cheeks and rail; the space or margin of the cut-water must be looked at; that is, the surface between the edge of the cut-water and the lower cheek; in a word, all must be seen at the first glance; hence we would always recommend that a draft be drawn, which costs less in time than to go through the operation we have described, besides having just what we want. The sheer-plan should be drawn, in order that we may adapt the head to the ship.

We would not tenaciously adhere to the ordinary cut-water, cheeks, and head rail, by any means; there are ships upon which they cannot be made to appear well, and upon which the plain bow, if extended out to a point, would make the best finish that could be made. It is more difficult to set the full figure on a cut-water that shall appear graceful, than the billet head or simple scroll; the reason is found in the difficulty in getting the bow-sprit high enough, and if the head is extended far enough to obtain the height we require, we have the cut-water farther out than we wish. The reason why the bow-sprit may not be raised above the ordinary height will appear obvious, if we but reflect

that it requires some security above to counteract the leverage on the bow; the bow-sprit should in all cases have a breast-hook or chock above to confine the bow together.

In delineating a ship's head, either on paper, in the mould loft, or on the ship, provision should be made for the security of the bob-stays; the head rail should be made to clear the bow-sprit shrouds; in a word, the whole effort of the head should be that of harmonizing all parts—no chafing. We sometimes see a ship's bob-stay braced off from the cut-water above its connection, in order to prevent its chafing the head; this at once exhibits a lack somewhere, and would be seen by a man of taste, as soon and as far as he could delineate one stay from another. In smaller vessels it would be difficult to delineate any determinate size or proportion for the heads of coasting vessels, or those adapted to the navigation of our rivers, inasmuch as an almost endless variety exists in model and description, and, consequently, in finish; in very many instances our coasting and river vessels would look much better without a head than with one; but the eye of the owner having become familiarized with its appearance, sees nothing amiss.

Having concluded our expositions on the heads and sterns, after having

delineated the general principles of construction sufficiently lucid for the mechanic of ordinary mind, who is willing to take the trouble to think, we shall, before entering upon the subject of sparring ships and other vessels, make some tangible remarks upon launching vessels, and thus set the fabric afloat after its construction, and before we spread the canvass to the breeze.

The casual observer when attending a launch is instinctively impressed with the idea that there is great danger of the ship falling over side-ways out of the cradle, or the bed upon which she rests, as soon as the shores are removed; this opinion is without foundation, inasmuch as the centre of weight must of necessity be located at the centre of the vessel transversely. To illustrate this, suppose a ship weighing when ready to launch 1000 tons, and that she were of equal density throughout; we will also assume that the ship was 40 feet wide, and was prepared for launching in a cradle of 13 feet wide, that being a trifle less than one-third of the breadth; we now have 25 tons of weight for each foot of breadth; now is it not plain, that if the keel were sided 16 inches, that there must be a leverage equal to $16\frac{1}{2}$ tons at each side of the keel, which should at once teach us that a ship would stand on her keel

alone, without a shore under her, provided the weight of materials were distributed equally on each side of the centre of the ship; but let us continue this leverage farther: we have assumed the cradle to be 13 feet, which furnishes an excess of weight equal to 162 tons; that is to say, that it would require a weight equal to 162 tons placed 6½ feet outside of the ways to cause an equipoise, or a liability to cant her transversely out of her cradle; hence we discover that it requires but reflection to show us that our fears are groundless. With regard to the width of the cradle, the narrower the better for the ship, but at the same time men must have room to work in getting out the blocks.

The reasons why a narrow cradle is best, may be found in the fact that upon the centre of the vessel the most of the weight is sustained, inasmuch as the decks are kept their proper distance above the keel and keelson by the stanchions, and the entire ship would be sustained on the keel with less strain to the structure, than at any other point; it then follows that the ways should be as near as may be, all things else considered—one third of the breadth of the vessel has been considered as a rule; but we know of no reason why it should be followed; if 13 feet furnish room enough to remove

the blocks when launching a ship of 40 feet beam, we cannot discover any reason why they do not furnish enough to do the same work for a ship of 50 feet beam; the width of the cradle is considered to be the distance between the outside of the ways.

With regard to the angle of descent for launching, it may only be necessary to say, that the weight of the vessel, and the surface of bilge ways, should influence us in this particular; if the vessel to be launched be a ship, 1 inch or 1½ inches to each foot of length will be quite sufficient; if the ship be very large and heavy, $\frac{1}{4}$ of an inch to each foot of length is an abundance, and even less will do; $\frac{1}{4}$ has been found to answer every purpose, but for long steamboats, intended for river navigation, 1 inch to each foot would be not any too much; in such cases the ways should not be wide, inasmuch as the surface of ways and the weight of the boat do not correspond; the boat being very light, will not counteract the glutinous properties of the tallow, (the substance commonly used for greasing the ways;) in such, and indeed in all cases, Castile soap should be used; 1 part of Castile soap to 2 of tallow is a fair proportion, and will prove an ample remuneration for the extra expense consequent upon its use. The ground ways should be arched where we may not be able to

obtain all the descent we require ; the curve should be regular—not more in one part of the length than in another ; the blocks under the ways may be spaced as the keel blocks are forward, but they should be somewhat closer aft ; the ways may cant inward, in proportion to the angle of dead rise ; there can be no determinate rule for this ; it is only requisite to have enough to prevent the packing midship from having too much drift, and to prevent the bilge way from inclining outward, which it undoubtedly would do, (and sometimes does ;) 1 inch to the foot of breadth is enough cant for the ways ; they should be spaced somewhat farther apart at the lower end than at the stem—from 3 to 4 inches is as much as is usual, unless the length of ways be very great, or much more than is usual. It has been customary to keep the outer edge of the ways fair, and spike a ribband on, extending above the surface of the ways some 3 inches their entire length ; against this ribband shores are distributed from 10 to 15 feet apart ; the heels secured against stakes in the ground, and the heads spiked into the ribband. Some builders prefer the mode introduced in this city by the late Isaac Webb : by this mode the ribband is secured to the bilge way, and the inside of the ground way is kept fair and straight ; the shores com-

ing against the way. By this mode it will be perceived that there is no more ribband required than the length of each bilge way, and we have the surface of the way exposed to view. It will also be perceived that below the edge of the bilge way the ribband extends the same as in the former case, but a remark seems necessary here : in relation to the strength of the ribband when on the bilge, there should be a great amount of strength in the timber itself, inasmuch as no amount of fastening that could be put into the ribband and bilge way, would compensate for this when the bilge way inclines out ; the ribband must be sufficiently strong in itself to keep the way inboard ; hence we say the ribband should be of oak, and thick, such as will not readily split ; to prevent which, fastening should be put through it edgewise ; there is no liability to splitting off the ribband when outside, inasmuch as the shores come against it above the face of the ground way, which effectually prevents any accident from this source. There is little danger to be apprehended from the starting of the ribband when either mode is adopted, provided the vessel is lively on the ways, and starts as soon or before the blocks are all removed ; the custom of holding the vessel until all the blocks are out, is wrong ; when the keel





blocks are removed, they are taken out aft first, and the shores at the same time, or in advance of the work as it progresses from aft; and before two-thirds of the blocks are out, the shores should be all out; the vessel hangs aft as the ways take her weight, and often cants a number of the blocks. If, however, she is not inclined to go when the blocks are all out, a battering ram or screw may be used; if a screw is placed against the end of the bilge way, there may be a strain put on it before the blocks are all out, and as the removing of the blocks advances towards completion, the strain may be increased on the screw; sometimes when a vessel is launched on tallow after being packed up several days, it is found very difficult to start her, and it has often occurred that the vessel of necessity was blocked and shored up again, the packing removed, and the ways regreased. In such cases, it has been found that the tallow has been so completely packed into a cake that it had no appearance of having the least slippery property; in other cases, when the weather has been hot, the tallow was melted, and to a great extent disappeared; hence we say, that Castile soap should be used. In the Navy, the packing is all fitted on the dry ways, and then removed, and the ways greased; and when it is designed

to let a vessel stand on the ways, and wait for orders, as is the case in the Navy, it is the proper mode, but if we are to launch as soon as ready, it is not necessary; neither is it necessary to hold the ship by bolting the bilge way, and sawing it off; (when for this reason, which is sufficient, were there no other:) if the ship has an inclination to go, we hold her; if she has no inclination, we hinder her; and when the ways are bolted, we cannot know until the blocks are out, or the ways are sawed off, and then there has been time lost; not that we suppose there is danger of her coming down, or getting out of the cradle, but of the tallow packing hard; the ship should be lively; that is, have a little motion, which keeps the tallow slippery.

With regard to the packing at the ends of the vessel, a ribband extends across the poppets, over which chains are extended that go under the keel and up the opposite side; these being wedged taut, support the ends of the vessel; sometimes cleets are spiked above the heads, but this is manifestly wrong, particularly on the bow; we have seen a fore wood broke entirely off by a set bolt placed over a cleet that was spiked on the bow.

When those poppets reach the after end of the ways, the sooner they get out of their place the better, pro-

vided there is water enough for the bow to drop; and if there is not, they can be held better by chains; there may be two ribbands, one at the heel, and another at the head; but when this is the case, the poppets should incline a very considerable inboard towards the centre from a perpendicular line at the head; it is not absolutely necessary that the heads of the poppets should be as far apart on the two sides at the head, as the packing midship; in other words, that the cradle the ship sets in, should be as wide at the ends as in the centre; besides, the poppets will hold up much more without the least slip when the heads are tumbled home.

The principal difficulty in launching long steamboats is found in the difference in the descent of the boat and the ways—the boat standing at a much smaller descent than the ways, the fore end of the ways are against the bow. When we find that we have not as much descent as we desire, we may let the mean descent be all, or a little more than we require, and arch the ways, so that the after ends will have, say $1\frac{1}{2}$ or $1\frac{1}{4}$ inches to the foot, and the fore end $\frac{1}{4}$, $\frac{1}{2}$ or $\frac{3}{4}$ of an inch—the circumstances of the case determining the amount in all cases; it is better to have a little more descent than is necessary, than not quite

enough; in the one case we have a good launch—in the other we have none; we are quite safe in saying that any vessel will go at $1\frac{1}{2}$ inch to the foot, and this is usually considered enough when both the ground and bilge ways are yellow pine, and have been used a few times; care should be taken that there is the same space or more for the fore foot to pass than its extension below the ways at the bow, else she may drag on the shore in passing out of the slip.

We shall assume that the ship is launched, and along side of the wharf, ready for her spars, and we now enter upon the duty of delineating the manner of adapting the spars to the ship. The various random modes of sparring vessels in all parts of the world have rendered this the most difficult and perplexing problem that has ever engaged the attention of commercial men; and so fairly and fully has the labor of devising an unvarying rule for masting and sparring ships and other vessels been divided, that there are almost as many rules as there are builders: each has carved out his own path, and each adheres with tenacity to his own darling project, which in ninety-nine cases out of every hundred, has no reference to the peculiarities of the vessel. Perhaps there is no branch of human knowledge that is kept so com-

pletely, so promptly within the precincts of the mind as the little that is known of what pertains to the science of sparring vessels.

The most remarkable feature connected with this whole subject of sparring vessels, is the fact that men have not dared to give utterance to a single thought that would tend to show the absurdity of the present course.

We shall endeavor first to show what are the most prominent rules in some parts of Europe, where, as in the United States, no reference is had to the peculiarities of the model presented by the exterior surface of the vessel to the fluid, from which is received all the absolute resistance that is to be overcome. We unhesitatingly say, that the annals of scientific knowledge does not furnish a parallel for absurdity : a ship is pronounced a bad or good model in the ratio of her performance, be it what it may, without the most remote reference to the location of the centre of buoyancy, or to the centre of effort of the sails ; in this particular, mechanics have all become sailors, continually looking aloft in the aerial regions for what can only be found beneath the surface of the water. It requires but a moment's reflection by the thinking man, to discover that the longitudinal centre of the lateral resistance must of necessity be the fulcrum,

each side of which the sail should be about equally balanced, allowance being made for certain contingencies, found principally in coasting vessels.

Force operates the same, whether it be that of the hand against the bow or stern of a vessel, or an equal amount in wind against the sail ; the masts of vessels are like so many levers, and although the power is distributed along the mast in the ratio of the altitude, each sail having a different size, consequent upon a separate location, yet the centre of the propulsive power of each sail is the point at which the effect takes place ; hence it follows that there must be a point that represents the force of all the sails, that point we have already denominated the centre of propulsion ; it then only remains to determine where this point should be located, and the universal dissolvent to this mysterious problem has been discovered. We should remember that we not only require its longitudinal location, but we require its altitude. In order that we may more fully understand the subject, it will not be amiss to examine the consequences of having an improper location ; first, if the centre of propulsion is too high, and the vessel is sailing before the wind, she will incline by the head, and her speed will be impaired ; if the centre of propulsion be too low,

the vessel will incline by the stern; this seems paradoxical, but is nevertheless true; and the reason is found in the fact that the bow is entering strong water, or water possessing its full share of buoyancy, and the pressure against the bow being at right angles with the surface of the fluid, imparts a lifting tendency to the bow, and, as a consequence, the stern must go down, inasmuch as the centre of propulsion is not high enough to counteract it; hence one of the reasons why ships do not perform in accordance with the wishes of those who command them; a tolerable good model is often repudiated in consequence of this mal-distribution of power. The effects of this unequal distribution is also seen when sailing on the wind; if the centre of propulsion be too far forward, she will not come to the wind readily, and what has been termed the lee helm will follow; and on the other hand, if the centre of propulsion be farther aft than its appropriate place, the vessel will carry a weather helm by inclining to the wind. It is difficult, however, to determine how much of the weather helm is attributable to the improper distribution of sail, inasmuch as the inequality in the two lines of flotation is the cause of the weather helm to a very great extent. The altitude of the centre of propulsion should be deter-

mined with reference to the vessel's performance when sailing before the wind; while the area of sail should be resolved with reference to the vessel when on a wind. Thus it will be discovered that the longitudinal and the vertical disposition of this point determines all that we require. Before, however, we endeavor to spread our sails, it is important that we know the ratio of stability the vessel may possess, as the whole matter rests here: if the vessel have a large amount of stability, we may be able to spread a large area of sail, but on the contrary, if we have but little stability, a small area of sail only will be required; hence it will be necessary to determine the amount of stability we possess in the manner we have shown in Chapter 3. It should not be forgotten that it is possible to make a vessel too stiff for a sailing vessel by artificial means; that is to say, by the distribution of cargo a vessel may be made so stable, or stiff, that her masts would be endangered by the sudden efforts to right herself when inclined by the wind or sea. This, it will be observed, would not arise from the size or dimensions of the ship if built by the proportionate dimensions we have furnished.

Before entering upon the exposition of our own views, we shall show what rules are adopted in some parts of

Europe. The *Danish* rule for masting and sparring merchant ships is as follows: The centre of the fore mast is located at $\frac{1}{4}$ to $\frac{1}{3}$ of the length of the load or constructed line of flotation from the forward perpendicular; its rake is set down at from $\frac{1}{2}$ to 1 degree—these being the extremes. The centre of the main mast from $\frac{1}{4}$ to $\frac{1}{3}$ of the load-line, abaft the centre of the same; the extremes of rake are set down as in that of the fore mast, variable, being from $\frac{1}{2}$ to 2 degrees. The centre of the mizen mast from $\frac{1}{4}$ to $\frac{1}{3}$ of the load water-line forward of the after perpendicular; the extremes of rake from 2 to 5 degrees; steve of the bowsprit 20 to 25 degrees. For barks, the centre of the fore mast is placed $\frac{1}{4}$ to $\frac{1}{3}$ of the water-line aft of the forward perpendicular; the centre of the main mast $\frac{1}{2}$ aft of the centre of the length of the load-line of flotation; the mizen mast and bowsprit as in ships. In brigs, the centre of the fore mast is $\frac{1}{4}$ to $\frac{1}{3}$ of the length of load-line aft of its forward perpendicular, to rake from 1 to 3 degrees; the main mast is placed from $\frac{1}{4}$ to $\frac{1}{3}$ of the length of the load-line aft of its longitudinal centre; its rake from 3 to 5 degrees; elevation of the bowsprit from 15 to 25 degrees. In schooners, the fore mast is usually from $\frac{1}{4}$ to $\frac{1}{3}$ of the length of the load-line aft of the perpendicular; rake from 4 to 10 degrees; the main mast $\frac{1}{4}$ to $\frac{1}{3}$ of the length aft of its longitudinal centre; rake from 6 to 10 degrees; elevation of the bowsprit 8 to 10 degrees. In cutters, sloops and yachts, the mast is from $\frac{1}{4}$ to $\frac{1}{3}$ of the length of the load-line aft of the forward perpendicular; they sometimes have no rake, and the greatest extreme of rake is set down at 4 degrees; the elevation of the bowsprit is set down at from 6 to 8 degrees. It will be observed that this description of vessels are all sloop-rigged, and that the term cutter does not denote in other countries a vessel having two masts.

We would deem the time vainly spent in delineating every description of small craft, and the crude manner of sparring them; there is, however, a vessel called the Galeas, unknown in the waters of the United States, and used in the Danish merchant service; the rig is very similar to that of the hermaphrodite brig in this country, with this exception—the main royal is not as taunt as that of the fore; we would call the after mast the main mast, but it is denominated the mizen mast by their builders. The main or fore mast is from $\frac{1}{4}$ to $\frac{1}{3}$ of the length of the water-line aft of the forward perpendicular; rake from 1 to 2 degrees; the mizen mast $\frac{1}{4}$ of the length from the after perpendicular to the

fore mast, set off forward of the after perpendicular; rake from 2 to 3 degrees; elevation of the bowsprit from 16 to 20 degrees. The length of the spars is as follows: for ships that have a good degree of stability, main mast (whole length) the moulded breadth of the ship $\times$ 2, and the depth from the lower deck to the keelson added; mast head $\frac{1}{4}$ to $\frac{1}{2}$ of the whole length; diameter 1 inch to every $3\frac{1}{2}$ feet of the same; the whole length of the top-mast equals the moulded breadth and the depth as shown; head $\frac{1}{4}$ of the whole length of the top mast; diameter in the cap 1 inch for 3 feet of whole length; (on ships of small stability $\frac{1}{4}$ or $\frac{1}{2}$ of the depth is taken for the lower and top masts; the topgallant is $\frac{1}{4}$ to $\frac{1}{2}$ of the top masts; in diameter 1 inch to 3 feet; royal mast $\frac{1}{4}$ to $\frac{1}{2}$ of the foregoing; pole $\frac{1}{4}$; main yards (whole length) the moulded breadth multiplied by 2 or $1\frac{1}{2}$; both of the yard arms $\frac{1}{6}$ of the yard; diameter 1 inch to every 4 feet of length; topsail yard $\frac{1}{2}$ of the main yard; both arms $\frac{1}{4}$ of the whole length; diameter 1 inch to 4 feet; topgallant yard $\frac{1}{2}$ of the topsail yard; diameter 1 inch to 4 feet; royal between $\frac{1}{4}$ and $\frac{1}{2}$ of the foregoing; diameter 1 inch to 5 feet of length; fore mast is $\frac{1}{2}$ of the length of the main top mast shorter than the main mast; the other dimensions are $\frac{1}{4}$ or $\frac{1}{6}$ of that of the main mast; mizen mast and its appended spars are, for ships from $\frac{1}{2}$ to $\frac{1}{4}$ of the main mast. In barks the mizen mast is the same length as the main mast; the mast head is $\frac{1}{4}$ of this length, and the diameter 1 inch for every 4 or $4\frac{1}{2}$ feet of length; spanker-boom $\frac{1}{2}$ of its length over the stern; in diameter 1 inch to every 4 feet of length; the gaff is $\frac{1}{4}$ or $\frac{1}{2}$ of the boom; diameter 1 inch to $3\frac{1}{2}$ feet of length; bowsprit outboard $\frac{1}{4}$ or $\frac{1}{2}$ of the moulded breadth; in diameter the size of the fore mast; jib-boom outboard of bowsprit $\frac{1}{2}$ of the foregoing length. For schooners the whole length of the main mast is 3 or $3\frac{1}{2}$ times the extreme breadth, and in diameter 1 inch for 4 feet; mast head $\frac{1}{4}$ to $\frac{1}{2}$ of the length; the fore mast from $\frac{1}{2}$ to $\frac{3}{4}$ of the main mast; the diameter and length of the head as the main mast; bowsprit outboard $\frac{1}{4}$ or $\frac{1}{2}$ of the breadth; diameter same as the fore mast; jib-boom outboard of bowsprit $\frac{1}{2}$ of the breadth; diameter 1 inch per 5 feet of the whole length; main boom $\frac{1}{2}$ of the distance from the main mast to the stern over the stern; diameter 1 inch for 5 feet; gaff $\frac{1}{4}$ or $\frac{1}{2}$ of the boom; diameter 1 inch for 4 feet; fore gaff 4 to 6 feet shorter than main gaff; main top mast 2 or 3 feet longer than half the lower mast; fore top mast $\frac{1}{2}$ or $\frac{3}{4}$ of the main; lower yard $1\frac{1}{2}$ to $1\frac{1}{2}$ of the breadth; diameter 1 inch to 4

feet; topsail yard $\frac{3}{4}$ of the lower yard; topgallant yard $\frac{3}{4}$ of the topsail yard. The Galeas have a fore mast twice their breadth added to twice their depth; diameter 1 inch per 4 feet; mizen mast $\frac{3}{4}$ of that of the fore mast; diameter 1 inch per 4 feet; bowsprit outboard from $1\frac{1}{2}$ to 2 times the breadth; diameter the mean of the masts; jib-boom outboard once the breadth; diameter 1 inch per 4 feet; fore top-mast $1\frac{1}{2}$ times the breadth; diameter 1 inch for every $3\frac{1}{2}$ feet of length; mizen top-mast $\frac{1}{2}$ of the lower mast; fore yard twice the breadth; topsail yard $\frac{3}{4}$ of the lower yard; diameter 1 inch per 4 feet; topgallant yard $\frac{3}{4}$ of the topsail yard; diameter 1 inch per $3\frac{1}{2}$ feet; fore boom 2 to 4 feet shorter than the distance between the masts; diameter 1 inch per $3\frac{1}{2}$ feet; mizen boom $1\frac{1}{2}$ to $1\frac{1}{4}$ times the breadth; gaffs are $\frac{3}{4}$ of the booms; fore mast head $\frac{1}{4}$ of the length of the mast above deck; mizen mast head $\frac{1}{4}$ of the whole length of the mast. Sloops, if vessels, have a large amount of stability, the length of the load-line of flotation is the length of the mast; if an ordinary amount of stability, 3 times the breadth; diameter 1 inch per 4 feet; head $\frac{1}{4}$ of the length of the mast; top-mast the length of the lower mast from the deck to the tressel-trees; bowsprit outboard 2 to 3 feet more than the breadth; jib-

boom $\frac{3}{4}$ to $\frac{1}{2}$ the length of the outboard part of the bowsprit; boom 2 to 6 feet over the stern; gaff is $\frac{3}{4}$ to $\frac{1}{2}$ of the boom. Cutters and yachts are sparred in the same manner. The *Danish* theory requires the centre of effort (or as we have termed it, the centre of propulsion) of the sails of square-rigged vessels to be $\frac{1}{4}$ to $\frac{1}{5}$ of the length between the perpendiculars forward of the centre of the length, and $1\frac{1}{2}$ to $1\frac{3}{4}$ of the extreme breadth above the water-line. On vessels without square sails, this point may be found at or aft of the longitudinal centre.

The *German* mode of sparring ships may be comprehended in the following manner: let L be the length between the perpendiculars (or between the rabbets) on the load-line, and B the moulded breadth; centre of the fore mast = $.16 \times L$ aft of the forward perpendicular; rake $\frac{1}{4}$ of an inch per foot; centre of main mast $.071 \times L$ aft of the centre of length; rake $\frac{1}{4}$ inch per foot; mizen mast $\frac{1}{4} \times L$ forward of the after perpendicular; rake 1 inch per foot; length of the main mast = $2.45 \times B$; diameter 1 inch per 3 feet; mast head $\frac{1}{8}$ of the mast; top-mast = $\frac{3}{4}$ to $\frac{1}{2}$ of the mast; diameter 1 inch per 3 feet; head .12 of its length; topgallant mast = $\frac{1}{2}$ of the length of the fore mast; 1 inch per 3 feet of length for diameter; royal mast $\frac{1}{4}$ of the former, and to this

add the pole $\frac{1}{2}$ of the royal mast; fore mast is in all its dimensions $\frac{1}{2}$ of the main mast; fore-top, topgallant and royal mast $= \frac{1}{2}$ of that of the main; the length of the mizen mast $= \frac{1}{3}$, and diameter $\frac{1}{2}$ of the main top-mast; the other top-masts are $\frac{1}{3}$ of the main top-mast, and the diameter $\frac{1}{2}$ of them; bowsprit outboard $= .8 \times B$; elevation 4 to 5 inches per foot; jib-boom the outboard of bowsprit $.68 \times B$; diameter $.6$ of an inch per foot of this length; flying jib-boom outboard of jib-boom $.51 \times B$; diameter $.5$ of an inch per foot of this length; main yard whole length $.49 \times L$; diameter 1 inch per 4 feet; both arms $\frac{1}{2}$ of the length; top-sail yard $= .376 \times L$; diameter 1 inch per 4 feet of length; both arms $.117$ of the length; topgallant yard $.258 \times L$; 1 inch per 4 feet of diameter; arms $\frac{1}{3}$ of the length; royal yard $.174 \times L$; 1 inch for every 4 feet of length; arms $\frac{1}{4}$ of the length; fore yards are as the main yards, or $\frac{1}{2}$ of the same; mizen or cross-jack yards are $\frac{1}{3}$ of the main yard; fore gaff $.207 \times L$; diameter 1 inch per 4 feet; main gaff $.167 \times L$; diameter 1 inch per 4 feet; mizen or spanker gaff $.207 \times L$; diameter 1 inch for 4 feet; mizen or spanker boom $.3 \times L$; 1 inch per $3\frac{1}{2}$ to 4 feet of length; fore leech of stay-sail $.6$ of its stay; foot leech $.75 \times B$; fore leech of jib $.75$ of its stay; foot leech

$.1 \times B$; flying-jib fore leech $.5$ of its stay; foot leech $.7 \times B$.

In locating the masts in brigs, the centre of the fore mast $= \frac{1}{2}$ of the length of the load-line forward of its middle; rake $\frac{1}{2}$ of an inch per foot; centre of the main mast $\frac{1}{2}$ of the water-line aft of its middle; rake $\frac{1}{2}$ of an inch per foot; all the other dimensions as in ships.

In *France* the following is the rule by which ships and barks are sparred: Let L be the length between the rabbets on deck; B the moulded breadth; centre of fore mast $= .29 \times L$ forward of the middle of the water-line; rake $\frac{1}{4}$ of the foot to each of length; centre of main mast $.155 \times L$ aft of the longitudinal centre of the length of water-line; rake $\frac{1}{2}$ of the foot; mizen mast $.365 \times L$ aft of the longitudinal centre of length; rake $\frac{1}{2}$ of the foot; whole length of the main mast $2.33 \times B$; diameter 1 inch per $3\frac{1}{2}$ feet; mast head $\frac{1}{2}$ of the length; fore mast whole length $2.25 \times B$; diameter 1 inch per $3\frac{1}{2}$ feet; mast head $\frac{1}{2}$ of the length; mizen mast whole length $2.22 \times B$; diameter 1 inch per 4 feet; mast head $\frac{1}{2}$ of the length; bowsprit outboard $.75 \times B$; diameter as that of the fore mast; jib-boom of the outboard part of bowsprit $.66 \times B$; diameter $\frac{1}{2}$ of the bowsprit; flying jib-boom of the outboard part of jib-boom $.5 \times B$; diameter $\frac{1}{2}$ of the jib-boom; main yard $= .5 \times L$; diameter

1 inch per 4 feet; both arms = $\frac{1}{4}$ of the whole length; the fore yard same as main; topsail yards $.375 \times L$; diameter 1 inch per 4 feet; both arms $\frac{1}{4}$ of the length; topgallant yards $.25 \times L$; diameter 1 inch per 4 feet; both arms $\frac{1}{4}$ of the length; royal yards $.184 \times L$; diameter 1 inch to $3\frac{1}{2}$ feet of length; both arms $\frac{1}{4}$ of the length; top masts $1.25 \times B$; diameter 1 inch per 3 feet; head $\frac{1}{4}$; topgallant mast $.66 \times B$; diameter 1 inch per 3 feet; royal masts $.66 \times B$; diameter 1 inch per 5 feet; pole $\frac{1}{4}$; mizen top masts $1.7 \times B$; 1 inch diameter for 5 feet; pole $\frac{1}{4}$; fore trysail, or fore spencer $2 \times L$; diameter 1 inch to 4 feet; main spencer gaff $.125 \times L$; diameter 1 inch to 4 feet; spanker boom, or mizen boom $.25 \times L$; diameter 1 inch per 4 feet; gaff $.154 \times L$; diameter 1 inch per $3\frac{1}{2}$ feet. The distribution for brigs are as follows: location and dimensions the same as those of barks, except the boom sail, or spanker, which equals $.483 \times L$; diameter 1 inch per 5 feet; gaff $.34 \times L$; diameter 1 inch per 4 feet; the jibs are the same as on barks; flying jib fore leech $.5$ of the stay; the foot leech $.7 \times B$ jib fore leech $.75$ of its stay; foot leech $1 \times B$; stay-sail fore leech $.6$ of the stay; foot leech $.75 \times B$. The schooner brig, or as it is termed in the United States, hermaphrodite brig, have the centre of the fore mast $.25 \times L$ forward of the middle of the water-line; rake $.083$ feet per foot; centre of main mast $.125 \times L$ aft of the middle of the water-line; rake $.25$ per foot; (L and B represent the same as on ships and barks;) main mast whole length $2.895 \times B$; diameter $\frac{1}{4}$ of the length; head $\frac{1}{4}$; fore mast whole length $2.25 \times B$; diameter $\frac{1}{4}$ of the length; head $\frac{1}{4}$; bowsprit outboard $.75 \times B$; diameter as the fore mast; jib-boom of the outboard of bowsprit $1.15 \times B$; diameter $\frac{1}{4}$ of the bowsprit; flying jib-boom the outboard of jib-boom $.5 \times B$; diameter $\frac{1}{4}$ of the jib-boom; main top-mast $1.8 \times B$; diameter $\frac{1}{4}$; pole $\frac{1}{4}$; fore top mast $1.25 \times B$; diameter $\frac{1}{4}$; head $\frac{1}{4}$; fore topgallant mast $.666 \times B$; diameter 1 inch per 3 feet; fore royal mast $.68 \times B$; diameter 1 inch per 4 feet; pole $\frac{1}{4}$; fore yard $.53 \times L$; diameter $\frac{1}{4}$; both arms $\frac{1}{4}$; fore top-sail yard $.39 \times L$; diameter $\frac{1}{4}$; both arms $\frac{1}{4}$; fore topgallant yard $.25 \times L$; diameter $.02$; both arms $\frac{1}{4}$; fore royal yard $.184 \times L$; diameter $.02$; both arms $\frac{1}{4}$; fore gaff $.25 \times L$; diameter 1 inch per $3\frac{1}{2}$ feet; main gaff $.3 \times L$; diameter 1 inch per $3\frac{1}{2}$ feet; main boom $.535 \times L$; diameter 1 inch per 4 feet; steve of the bowsprit from a horizontal line $.42$ feet.

The *English* mode of sparring ships is as follows: Let L be the length between the stem and post on deck, and

B the breadth to the outside of the wales; whole length of main mast $\frac{L+B}{9}$; diameter $\frac{1}{3}$ per 3 feet; fore mast $\frac{1}{2}$ of the main mast; mizen mast $\frac{1}{3}$ of the main; diameter $\frac{1}{3}$ of the main mast; main top-mast $\frac{1}{2}$ of the main mast; diameter 1 inch per 3 feet; fore top-mast $\frac{1}{2}$ of the main top-mast; mizen top-mast $\frac{1}{3}$; diameter $\frac{1}{3}$ of the main top-mast; topgallant mast $\frac{1}{2}$ of the top-mast; diameter 1 inch per 3 feet; royal masts $\frac{1}{2}$ of the topgallant masts; diameter $\frac{1}{3}$ of the topgallant masts; whole length of bowsprit $\frac{1}{2}$ of the main mast, outboard $\frac{1}{2}$ of this length; diameter as that of the fore mast; jib-boom outside of cap of same, as the bowsprit outboard; diameter 1 inch for $2\frac{1}{2}$ feet of length; flying jib-boom $\frac{1}{2}$ of the jib-boom; diameter $\frac{1}{3}$ per 3 feet; main yard $\frac{1}{2}$ of the main mast; diameter .7 per 3 feet; fore yard $\frac{1}{2}$ of the main yard; mizen, or cross-jack yard, same as the fore top-sail yard; diameter $\frac{1}{3}$ per 3 feet; main top-sail yard $\frac{1}{2}$ of the main yard; diameter $\frac{1}{3}$ per 3 feet; fore top-sail yard $\frac{1}{2}$ of the main top-sail yard; mizen top-sail yard $\frac{1}{3}$ of the main top-sail yard; topgallant yard $\frac{1}{2}$ of the top-sail yards; royal yards $\frac{1}{2}$ of the top-sail yards; mizen boom as the main top-sail yard; gaff $\frac{1}{2}$ of the boom; diameter $\frac{1}{3}$ for 3 feet of length.

The rule for masting ships in the United States is doubtless the most

variable on the globe; the most prominent builders each profess to have a mode peculiar to himself. We have taken from several of the best proportioned double-decked freighting ships some tangible results; not, however, as to the mode of adapting the stations and dimensions to the peculiarities of the model, for this would be admitting that ships are thus sparred, which we do not. We cannot entertain the most distant idea that any system is adopted in this more than in any other country of sparring ships or other vessels—all the changes that are made from the common rules, or well-known usages, are made in accordance with the opinion of the builder, without reference to the lateral resistance, the very basis of propulsion by sails; but while American ship-builders vary from the rules of a stereotyped age, there is good reason for the belief they will yet recognize a system worthy of themselves, of the age, and of the country in which they live. The following is the result of the deductions referred to:—Take of 760 parts of load-line from aft side of stem to fore side of post; 150 parts to centre of fore mast; from thence to centre of main mast 264 parts; from thence to centre of mizen mast 211 parts, and 135 parts will remain; $\frac{1}{2}$ of the length on load-line should be the length of the main mast; fore mast $\frac{1}{2}$

of the main mast; mizen mast $\frac{1}{3}$ of the main mast; main top-mast $\frac{1}{3}$ of the main mast; main topgallant mast $\frac{1}{3}$ of the main top-mast; royal $\frac{1}{3}$ of the topgallant; sky-sail mast $\frac{1}{3}$ of the royal; main yard $\frac{1}{2}$ of the length of the main mast; main top-sail yard $\frac{1}{4}$ of the lower yard; main topgallant yard $\frac{2}{3}$ of the top-sail yard; main royal $\frac{1}{3}$ of the topgallant; main sky-sail $\frac{3}{8}$ of the royal. The fore top-mast, topgallant and royal should bear the same ratio to the lower masts that the main does; likewise the mizen top-mast, &c. The fore yard, top-sail yard, topgallant and royal will stand in the same ratio as the main; the mizen likewise will stand so related; as a consequence the fore yard will be $\frac{1}{3}$ of the main yard; and the fore top-sail yard $\frac{1}{4}$ of the lower yard; the topgallant $\frac{2}{3}$ of the top-sail yard, &c.; the cross-jack yard $\frac{1}{4}$ of the main yard; mizen top-sail yard $\frac{1}{4}$ of the cross-jack yard; bowsprit outboard $\frac{1}{2}$ of the fore mast; jib-boom $\frac{1}{4}$ of the outboard part of bowsprit; spanker-boom $\frac{1}{2}$ the length of the fore mast; gaff $\frac{3}{4}$ of the length of the boom. This rule will also apply to brigs.

The following method is sometimes adopted for proportioning the spars of a ship—main mast $2\frac{1}{2}$ times the ship's beam; fore mast equal to $\frac{2}{3}$ of the main mast; mizen mast equal to $\frac{1}{3}$ of the

main mast; bowsprit $\frac{3}{4}$ of main mast; $\frac{1}{2}$ inboard; main top-mast $\frac{2}{3}$ of the main mast; main topgallant mast $\frac{1}{3}$ of the main top-mast, exclusive of the pole, which is usually $\frac{1}{3}$ of the topgallant mast; fore top-mast $\frac{2}{3}$ of the fore mast; fore topgallant mast $\frac{1}{3}$ of the length of the fore top-mast exclusive of pole, which is as on the main; mizen top-mast $\frac{2}{3}$ of the mizen mast; mizen topgallant mast $\frac{1}{3}$ of the length of the mizen top-mast; pole as fore and main; jib-boom length of the bowsprit, $\frac{1}{4}$ of which is outside of cap; main yard twice the ship's extreme breadth; main top-sail yard $\frac{1}{3}$ of the main yard; main topgallant yard $\frac{2}{3}$ of the main top-sail yard; fore yard $\frac{1}{3}$ of the main yard; fore top-sail yard $\frac{1}{3}$ of the fore yard; fore topgallant yard $\frac{2}{3}$ of the fore top-sail yard; royal yards $\frac{1}{3}$ of the length of the respective topgallant yards; cross-jack yard same as main top-sail yard; mizen top-sail yards same as main topgallant yards; mizen topgallant yards two-thirds of the mizen top-sail yard. Sprit-sail yards are sometimes carried, and are $\frac{1}{3}$ of the fore top-sail yard; spanker-boom the length of the fore top-sail yard; mizen gaff $\frac{3}{4}$ of the spanker boom. Top-sail yard arms are usually longer than others, in consequence of their being oftener reefed, and the arms should be adapted to the hauling out of the close reef earing.

Masts are placed often by the following rule: divide the length of the upper deck between stem and post into 360 equal parts; place the fore mast on the 69th from forward; the main mast 124 parts from the fore mast; the mizen mast on the 99th part from the main mast; rake of fore mast $\frac{1}{4}$ of an inch to every foot of length; main mast $\frac{1}{2}$; mizen mast 1 inch; steve of bowsprit $4\frac{1}{2}$ inch to each foot of length from a horizontal line.

The methods for masting schooners is so variable that little tangible information can be derived; the hoist of sails ranging from twice to $2\frac{3}{4}$ times the breadth of beam. The masts are sometimes stationed in the following order: divide the length of the deck into 756 parts; take 192 from forward for the centre of the fore mast; 258 from the centre of the fore mast to that of the main; and 336 parts for the foot leech of the fore sail, and 408 for the foot leech of the main sail; one half of the latter for the head leech of both sails; 348 parts for the foot leech of the jib. These proportions apply principally to fast sailing coasting vessels, but flat wide schooners with centre-boards have a greater proportion of sail; there is no rule that is invariable. The schooners of the United States are not built like our ships, principally in the large cities; they are

built wherever timber and capital are found, and water enough to launch them; hence the reason why such diversity in dimensions, shape and distribution of sail. For sloops the spars are less variable: hoist of main sail $2\frac{1}{2}$ times the breadth; foot leech 3 times the breadth added to the depth; after leech 3 breadths added to 3 depths of hold; jib-stay same as foot leech of main sail; after leech of jib same as hoist of main sail; head of main sail 1 breadth and 3 depths added; foot leech of jib the same; station of mast, $\frac{1}{4}$ of the breadth from the forward part of deck; rake $\frac{1}{4}$ inch to the foot; schooners from $\frac{1}{4}$ to $\frac{1}{2}$ inch. With regard to the rake of masts, there seems to be an error that prevails almost universally; the original design in raking masts is to get lifting power in vessels with fore and aft sails; both masts are raked as if both ends could be lifted with the power of the wind at the same time. It must be plain, we think, that if the vessel displaces a volume of water equal in weight to the weight of the vessel, that of the bow is depressed by the power of the wind; the centre of propulsion is too high or too far forward; hence it follows, that whatever power is expended in endeavoring to lift the vessel, is lost in propelling her onward; and if the vessel's head is depressed, it is not because the masts do

not rake enough, but because the altitude of the centre of propulsion is above a just proportion of this lifting tendency, consequent upon the rake; were this what it is assumed to be, the proper mode would be to rake the fore mast only; it, however, should be remembered, that any very considerable rake to a vessel's mast has a tendency to depress the vessel when an inclination takes place: the lifting power operates against us when the vessel is careened to any very considerable extent. To mariners it has been a matter of wonder how the vessel's bow could be so much depressed while the head sails were set at a powerful lifting angle; the bellying of the sail itself, were there no other influence, is depressive in its tendency; and although by raking the masts of vessels we move the centre of propulsion farther aft, which is in itself important when required, yet the gain in lifting the vessel is much less than is generally supposed; were the masts to be set directly perpendicular to base-line, they would appear to incline forward, and indeed they actually would so incline when the vessel was under a press of canvass. We are not opposed to the raking of vessels' masts; enough to impart life is sufficient, and this amount would not materially influence the vessel. It has been found necessary to rake the mizen

mast of ships more than the fore mast, in consequence of the mizen top-sail being in close proximity to the main, causing the current of wind when leaving the main top-sail to strike the weather leech of the mizen top-sail aback, when close haul upon a wind; but while it is necessary in many cases to rake the mizen mast more, it is not necessary to extend the special grant to the main, inasmuch as the extra rake to the mizen was designed to clear the two top-sails; and it must be quite apparent, that to rake the main mast more than the fore mast, (because the mizen mast has been,) is to counteract the effects of what has been gained by the extra rake of the mizen. We readily admit that to the eye there seems to be a fair distribution of rake, because we have been accustomed to see the masts of a ship thus disposed; but the principles of utility owes no allegiance to this false standard: it must be quite clear, that if the main mast were raked less, the mizen would require less; schooners and sloops furnish a clear exemplification of the position: while the schooner's rake is variable, ranging from $\frac{1}{4}$ to $1\frac{1}{4}$ inches to the foot, the sloop ranges from $\frac{1}{4}$ to $\frac{1}{2}$ of an inch to the foot; the only exception to this rule worthy of notice, is the small fishing smack.

It is notoriously true that the sloop

can shape her course closer to the wind than the schooner. We, however, are frank to admit, that this discrepancy in the schooner is not wholly consequent upon the rake of her masts. The wind will act more effectively on one sail than two, though there be even somewhat more area in the two than in the one. This may be accounted for upon philosophical principles: when the schooner is on a wind, the after leech of the jib bellies or bows to leeward less than the part just forward of the leech; this is because the leech of the sail has the strain of the jib-sheet to keep it taut; the wind passing out of the jib strikes the fore sail on the lee side, and destroys its efficiency as far as its influence is felt. Just so with the main sail: the wind leaving the fore sail operates in the same manner. It is true that the sloop has the same difficulty with her jib, but her main sail is large, and the proportionate draw-back is small, being only on one sail; square-rigged vessels have an advantage that fore and aft ones do not possess; not because their sails are larger, which is not the case, but because they are enabled to trim the sails much nearer the perfect plane, consequently this deleterious influence of one sail upon another is not felt so much.

It will appear obvious to the discerning mind that the square top-sail can

be prevented from bellying out to leeward much better than the main sail of the schooner or sloop, for the manifest reason that the square sails of the ship can be sheeted home at both corners, and if the yards should bend under the strain in sheeting home, the lifts can be kept sufficiently taut to counteract the extra strain; hence we discover that the flow of fore and aft sails is much greater than that of the square sails, in consequence of the inability to spread the fore and aft sails as near the perfect plane.

With regard to the location of the masts of ships, brigs, schooners or sloops, the grand secret does not lie in the mere location of the masts, but in the locality of the centre of propulsion. This point, like the centre of gravity, represents all the forces that propel the ship. For example: the three top-sails of a ship are supported by the yards; the yards are supported by the masts, and the masts are supported and stayed by the hull; but is it not plain that either or all the top-sails may be held in equilibrio by a single four-stranded rope of a size adapted to the force? To accomplish this, it is only necessary to find the centre of gravity of the sail; that is to say, find that point around which there is an equal area of canvass, whether vertical or horizontal, as we have shown in Plate

1 and Plate 20; this point being found, we may assume the four-stranded rope to be unlaid a suitable distance from one end; the standing part being stretched and kept in horizontal line with the centre of gravity, and made fast; let the four strands be made fast to the four corners of the sail, is it not plain that the effect is the same as though the wind filled the sail when suspended to the yard? and will not the rope sustain all the force consequent upon the filling of the sail by the wind, even though the sail were loosed from the yard? and if it is the case in one sail, is it not so with regard to all the sails? and may they not all be represented in the same manner?

It is quite a common expression (in reference to the propelling power of a ship) to say that her fore mast (for example) is too far forward, or that she has too much head sail, or that she has not enough head sail; that her masts are too far aft: these, we say, are common expressions, and familiar to almost every commercial man; but is not the same effect produced when the sails on the fore mast are reduced or increased? We expect by moving (for example) the fore mast farther aft, with all the sails unaltered, to reduce the pressure on the bow; not by reducing the sails, but by bringing the propulsory power of the fore mast

nearer the middle of the ship; if the mast remains, the same thing may be effected by reducing the sails; these remarks apply to the other masts. The difficulty lies here: we have become accustomed to see the fore mast nearly as high as the main mast, and the mizen mast still shorter than the fore mast, and a certain adaptation of the yards; and while there is no manifest departure from this hoary practice, all is well; but let the masts remain, and reduce or increase the sail by adapting it to the model, and doubtless the objection will at once be heard. On the ordinary model the difference would not in many instances be manifest, but let the ship be designed for speed, and the centre of buoyancy located at or aft of the longitudinal centre of length, (inasmuch as this locality has been proved to be the best for high speed,) and the discrepancy will be but too manifest. When the length is divided into a given number of parts, without reference to the breadth, for stationing the masts of a ship, it must be plain that the rule would place the masts in a scow of the same length in precisely the same location as those of the ship; and it does not follow that because the ship is of uncommon length that she is able to bear sail in proportion; neither will it answer to have exclusive reference to the breadth in

masting and sparring ships ; nor yet to the centre of buoyancy, to the exclusion of all other points. There is another point in connection with the centre of buoyancy that should be noticed, if we would have the ship work well. We will draw our deductions from well-proportioned ships ; that is to say, those on which the greatest transverse section is at, or very near the centre of the vessel ; and, as a consequence, in the present state of advancement, the centre of buoyancy would be about the centre or somewhat forward of that locality. We will now determine the longitudinal centre of the lateral resistance ; this point cannot readily be determined from the draft ; hence, in order to make the subject clear, we shall resort to other means, and adopt another medium through which to furnish our expositions. The model, we think, will furnish all that we require ; assuming that the model of a ship were varnished, it would not be materially injured by being immersed as high as the load-line of flotation ; in order, however, to secure an equilibrium in an upright position, it will be necessary to screw a piece of batten on the top extending across the middle line at some length, on which a weight may be secured, that will cause the model to equipoise transversely ; the batten being placed on a vertical line over the centre of buoyancy, let the model now be placed in water as deep as the load-line of flotation ; it may then be assumed that the model rests on a sheet of still water, of sufficient extent to be moved freely in any direction, supported by the centre of buoyancy, and that point at the centre of length longitudinally. We may now determine the centre of the lateral resistance in the following manner : insert a nail at the centre of buoyancy, to which connect a string, and then take the angle the middle line of the model forms with the side of the box basin, or side of whatever the water and model may be placed in ; let the model be drawn side-ways by the string a considerable distance, and again take the angle of the middle line as before, when we shall be able to determine which end of the model has the preponderance of lateral resistance ; the end having the least will have moved the greatest distance ; we may, after having adjusted the string, try again ; not, however, before inserting another nail and string of equal weight on the opposite end of the centre of buoyancy, to counteract the leverage of the one we propel by ; it will be perceived that in the first instance the nail and string were at the centre of buoyancy, and was not unduly inclined to either the bow or the stern ;

but now in the second trial we have the nail and string on one end, and, consequently, the same or an equal distance from the centre of buoyancy, on the other end we must append an equal weight; we again take the angle as at first, and then draw the model side-ways as before; we may require not only this second, but several subsequent trials, before we shall have determined the correct location of the centre of the lateral resistance; having found this point in the manner described, which will most likely be aft of the centre of buoyancy, inasmuch as the cavity of the run augments the lateral resistance; in a word, the impressive sameness in most models leads us to draw this inference: if the model be that of a ship, and be quite full, or as full as freighting ships usually are, the centre of propulsion should be quite as far forward of the centre of buoyancy as the centre of lateral resistance is aft of the same; and the reason why this departure should take place, may be found in the fact that the inequality in shape of the two lines of flotation, causes the vessel's bow to incline to the wind; and the reason will appear manifest if we but remember that from the dead-flat frame on the lee line of flotation to the wood ends the distance is much greater than on the weather line, and inasmuch as the

pressure or resistance is met at right angles from the immersed surface, a much greater amount of resistance is found on the leeward than on the windward side; and, as a consequence, the preponderance of propulsion is required on the forward side of the centre of buoyancy, to counteract its influence.

On Plate 20 we have shown the distance of the centre of propulsion to be 8 feet forward of the centre of buoyancy, and yet the ship is lightly sparred and has less than the usual proportion of head sail, while the model exhibits less of this leeward preponderance than perhaps any freighting ship of equal breadth and displacement, and yet her performance warrants us in announcing the distribution to be all that could be desired; but this arrangement could not be carried out with equal success on all freighting ships, and for the following reason: the ship referred to has an equal distribution of buoyancy on each side of the longitudinal centre at the load-line of flotation, which is rarely the case in sailing vessels of any description; but it does not follow that the centre of the lateral resistance is also in the centre of length; the rake of the stem causes a loss of lateral resistance on the bow, while the surface of the rudder increased its amount on the after end; hence we discover that the centre of buoyancy was between

the two points, and about equidistant from each. It must not, however, be supposed that because full ships require more sail forward than this ship, on account of the greater inequality in the form of the lines of flotation, that the distance between the centre of buoyancy and the centre of propulsion should be augmented; for this reason the centre of buoyancy is farther forward on the full bow, and the centre of lateral resistance farther aft; hence we find that the locality of those points furnish an index to the apportionate distribution of sail.

We have another demonstration in Plate 1; there we see the centre of propulsion about $3\frac{1}{2}$ feet forward of the centre of buoyancy, and when we remember that the vessel shown in Plate 1 is but about 70 feet keel, and that the other on Plate 20 is about 170 feet keel, we shall at once recognize the analogy in the proportions of the distance between the two centres of the two vessels; here we have another exemplification of the advantages of blending practice with science. The vessel shown in Plate 1 furnishes an exhibition of the advancement of science in the Old world, while Plate 20 illustrates the approximation to maturity in the New.

In Plate 24 we are shown a pilot-boat on which the centre of buoyancy

is aft of the longitudinal centre; and although the form of the vessel is such as to bring the centre of the lateral resistance equally as far, if not still farther aft, yet we say this rule is equally applicable to this description of vessel, and in some instances where the equalization of the form of the two lines of flotation is complete, the centre of propulsion may be located at the centre of the lateral resistance.

In Plate 25 we have another illustration in the sloop *Victorine*; this vessel, a remarkable fast sailer as we have already shown, has her centre of buoyancy somewhat less than 2 feet forward of the longitudinal centre, and the centre of lateral resistance is about 3 feet aft of the longitudinal centre, as shown by the sirmark B; but this is not all: the centre of propulsion is forward at the same point; in this case we discover the centre of buoyancy, which is at the sirmark A, to be nearly 5 feet forward of the centre of lateral resistance. The casual observer may be able here to discover the cause, viz., the rake of the stem forward, and the preponderance of surface to the centre-board on the after side of the centre of length, in addition to the skeig-like shape of the after end of the immersed part; in this case the rake relieved the bow to a very considerable extent of the effects of the ine-



quality in form of the lines of flotation, and the centre-board served as a regulating medium.

In Plate 29 we have still another illustration of the advantages of keeping the centre of propulsion aft when the centre of buoyancy is near the longitudinal centre; we may there discover in the sirmark marked A the centre of buoyancy, and in the respective dotted lines, first B, the centre of propulsion when the jib, fore and main are set; in C, we see the centre of propulsion when the three lower sails and the stay-sail are set, and we find it still farther aft at D when the gaff top-sail is also set; hence we discover that in spreading those light sails the centre of propulsion is carried farther aft than the 3 principal sails demand. The centre of lateral resistance on Plate 29 is about equidistant aft from the centre of propulsion B, that the centre of buoyancy is forward of the same; and doubtless under some circumstances it is at the same (point, or) longitudinal locality. Chapman's *Area of Sails* is doubtless the best work upon the subject that has ever appeared in the Old world, and his theory is carried out to a greater extent than that of any other theorist that ever wrote upon this important subject: his works, however, are very rare—there being but few copies in print. In the work

alluded to, he informs his readers that the altitude of the centre of gravity of sails (or as we have termed it, the centre of propulsion) should be higher or lower in proportion as the ship is fuller or less so below the load-line of flotation. This is a manifest error, and requires an exposition that will at once make it fully appear: by Chapman's theory the ship that was made full below to make up a deficiency in the breadth, would have the altitude of the centre of propulsion higher than another ship having a good breadth with less fullness below; thus he would in effect increase the amount of sail on the vessel having the least stability, and diminish it on the ship that had the most.

It is notoriously true, as we have already shown, that ships that are narrow and deep, being full below, are stable only when light: that the bulk of cargo creates artificial and not natural stability; and, consequently, more than a mediocrity of sail should not be carried upon such ships.

In conclusion we say, that on ships or other vessels, modelled with direct reference to the purposes of utility, the centre of *effort*, or as it has been denominated, the *meta* centre, is the point that should govern us in locating the altitude of the centre of propulsion, inasmuch as this is an index that

indicates the stability of the vessel, or her power to resist inclination from the vertical position, whether transverse or longitudinal. In smaller vessels this calculation is seldom entered into; comparative localities furnishing data sufficiently near for all practical purposes; and we will add, that the sharper the bow longitudinally, the nearer the centre of propulsion may be located to the centre of lateral resistance.

With regard to the proportionate diameter of spars, our remarks on the concluding pages of Chapter 9 will furnish data sufficiently comprehensive to the ordinary mind; the settings-off are usually marked on the rule with a piece of chalk; these comprehend half of the diameter at the several equal divisions of length into which the spar is divided; hence it must appear manifest that there must be a spot on the rule, or half-diameter for every division of length on the spar; it should always be remembered that all settings-off on spars are made from the middle line; so with the settings-off, in length they are measured from the centre of length each way when the spar is a yard, because the slings are at the centre; but if masts, the partners are the largest part; if top-masts, the cap is the largest, except just at the heel, which is usually left square; for jib-booms

the cap should be the largest part; gaffs $\frac{1}{2}$ to $\frac{3}{4}$ of the length from the end on which the jaws are; booms at the locality of the sheet. The division of the circumference of the circle in eight equal parts for the eight-square, may be found on almost any carpenter's rule; the sixteen-square contemplates the equal division of each square into 4 equal parts; the 2 middle will show the size of the sixteen-square.

Yacht building next comes in for a share of our attention. It were vain to speculate on the advantages to commerce accruing from the introduction of this particular description of vessels—of the antiquity or utility of the custom of building vessels for the avowed purpose of pleasure, it is not our province to inquire; nor would Americans (whose crude notions of science in ship building are regarded by a portion of the English press as little better than a contemptuous violation of royal mandates) have ventured to cross the threshold of the sporting circles of the Old World, had not their unparalleled success in every branch of commercial art engendered the conviction that the genius developed by the institutions of the New World were quite as favorable to excellence in yacht as ship building.

The yacht squadrons of Europe, whose owners are the representatives

of hereditary knowledge, viewed with a kind of contemptuous complacency the humble pretensions of an American ship builder at yacht building. The sequel, however, afforded abundant proof that knowledge is not commensurate with wealth, nor experience with age, and that not a few of the yachts, as well as other vessels of the Old World, have been, and are now propelled with the *wrong end foremost*.

The preaching of Paul at Ephesus scarcely produced a greater sensation among the idolatrous Ephesians, than did the *Yacht America* among the sporting circles of the Old World. American ship builders have ventured to look beyond the battlements of war for perfected models in the messengers of peace; nor has their vision been confined to the *studio* of the philosopher, who would bend the channels of commerce into his untried theory, and hinge the science of ship building on the solution of a single problem; much less are they willing to commit the interests of this important art in the United States to the dictation of the periodical press of England, even though it be mantled with the guise of mechanism. And although the ship builders of the United States may have been deemed refractory by the philosophers of the Old World, yet we trust that it will be regarded as a sufficient apology, (when told that the United States are young as a nation, and, consequently, her experience must of necessity be limited,) that their vessels, whether *sailing* or *steaming*, have *no* superiors, and that it would perhaps be quite as well to continue the consultation of the same chart which has pointed unmistakably to the channel of *success*, and which to them, and to the mechanical world, is sufficiently legible, even though it may not seem quite clear to a small portion of the transatlantic press. They, however, have had a sufficient amount of experience and research to enable them to discover that the man who knows so little of the *practical* operations of a ship yard, as to be unable to tell how many sixteenths of an inch are contained in one foot of an ordinary mechanic's twelve-inch rule, has gone beyond his depth when *he* undertakes a crusade against American ship builders. We are frank to admit that they have not followed the metaphysical abstractions of their ancestors, and that they are unwilling to endorse the adage, which teaches that Britannia rules the waves; and however little they may know of the theories of ancient or modern philosophers, or even of the researches of the renowned

hero of a London Mechanical Magazine, they know that no sophistry can make that right which *common sense* pronounces wrong; and they have learned still more, that the best theory is that which is proved by practice, and can point to their ships as the best evidence *they* are able to furnish the world, that their theory and practice agree to demonstrate the correctness of their works on Marine and Naval Architecture; and that the principles upon which their practice is based, will live when the invective gall of an editor, or the fury of their jealous neighbors, has passed away—Time's boundary sundered, and commercial operations come to an end.

Experiments have been, and still are, regarded in Europe as the best means for materially improving this ennobling art; but of what avail has the many experiments in submerged blocks of various forms been to the marine of England, France, or other parts of Europe? Their vessels furnish the clearest exposition, and requires no comment from us. Experiments are valuable in maritime pursuits; but let their management be given to practical men, and let the subject be the vessel itself, (as in this country,) every ship that is built by a new model is an experiment, and surely Americans should be the last peo-

ple to disclaim experiments; but let them combine both theoretical and practical knowledge, and there is little hazard in ensuring success.

The Yacht America was an experiment, and during the progress of her construction, was regarded as a failure by not a few of those who cannot look into *nature's law of utility* for themselves—who can only see what some one before them has seen. Among the very few practical ship builders of the United States, (the weight of whose judgment was no longer a problem for solution,) none was to be found who rejected the principles involved in her construction. The experiment consisted chiefly in the more acute angle of her line of flotation on the anterior part, consequent in part upon having located the greatest transverse section farther aft than on other vessels of similar model. The wave line principle, carried out in the construction of the America, had been successfully adopted in some of the pilot boats of our coast with abundant success—the tables of one and the lines of another may be found on page 350, and plate 24. The Mary Taylor and the Moses H. Grinnell are very similar in form to the America, and we have little doubt but that the latter would have been quite a match for the best sailing vessel in the yacht



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squadron of Europe, had she been sent on such a mission; and unless the yacht builders of the Old World are prepared by their recent defeat for greater improvements in the speed of their vessels, it will not again be deemed necessary to build a vessel expressly for comparing the altitude of the speed of the Western World with that of Europe. But superior speed is not the only quality furnished in the models referred to; the vessels thus built are stronger, more comfortable, and, as a consequence, render life more secure; the resistance on the bow of a vessel (upon which the water is not heaped up) serves to hold her together; thus we find that where resistance is diminished, strength is increased; but this is not all: the vessel is steadier, the pressure being brought to bear on the sides of the vessel, instead of on her ends, serves to increase her practical stability, which is an item worthy of consideration.

The commercial world have a right to expect a higher rate of speed from this description of vessels than from any other, in addition to which, a combination of sea qualities should be commensurate with their speed. That the distribution of the propelling power has much to do with the success of this as well as other descriptions of sailing vessels, must be quite apparent,

and the same rules which we have shown to be applicable to larger vessels, are equally applicable to these. Plate 30 furnishes the lines and location of the masts of the Yacht America, whose builder is favorably known and recognized in connection with our remarks on the Mary Taylor and Moses H. Grinnell.

It may not be out of place to end this chapter with some general remarks on the altitude of mechanism as developed in ship building.

When we contemplate the various gradations of progress in the art of ship building, the variety of phases presented to the mind of him who studies its history, we can hardly fail to admire the beauties of this important branch of commercial art. If we go back to the time when the Sandwich Islander plunged beneath the briny wave, astride the round-ended plank, and contrast *his* knowledge of the laws of flotation with our own—if we measure the knowledge of the art as developed in the bark canoe, decked with the skin of beasts, portraying the altitude of the art in savage life, or following the scintillations of light, flashing athwart the mechanical horizon of a barbarous age, and contrast the coracle of Britain with her ships of the present time—if we press our inquiries still farther, and

roll back *Time's* progressive car, dissolving two thousand years of the past in the crucible of history, and in that time-honored era freight the car of the destroyer with the Tyrian shallop that carried tin from Britain; speed on the wheels of progress with the precious relic, until she floats upon the Atlantic's tumultuous tide beside those engaged in the same trade at the present day. We may go farther, and continue our researches, by fathoming every step of the world's advancement through the vista of time, down to the latest now; and we shall discover that the progress of this commercial art is the index to the *world's* history; and whether developed in the plank, the raft, or the canoe, the junk of the Chinaman, the shallop of the Phœnician, or the galley of the Carthaginian, they alike proclaim this universal truth. The coracle of Britain, the bark of the Dane, or the carrack of the Portuguese, alike impelled the march of civilization in the exhibition of the progress of mechanism as developed in this excelling art. The Dutch Galliot, the Spanish Galloon, and the Venetian Gondola, each in their turn served to give light and motion to civilization. The Polacca of the Levant, the ship of Great Britain, and the schooner (*Yacht*) of *America*, have all contributed to quicken the impulses of humanity, to extend the boundaries of civilized life, and to exhibit the glory of mechanism in the scientific construction of this stupendous fabric.





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* YACHT AMERICA.—Tonnage, 171.—Dimensions.—Length on deck, 24 feet; moulded breadth, 23 feet; depth, 2 feet; bowsprit out-board, 18 feet. Length of foremast, 72.5 feet, 7 feet of which is head; length of mainmast, 81 feet; length of main boom, 88 feet; length of gaff, 26 feet; length of fore gaff, 21 feet.

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